Explanation of sheet 13.Part of the coas

Memoirs of the Geological Survey, SCOTLAND.

EXPLANATION OF SHEET 13.

PART OF THE COAST OF AYRSHIRE.

EDINBURGH:
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1869.

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INDEX
to the
GEOLOGICAL SURVEY MAP
of
SCOTLAND

Published on the Scale of One inch to a mile

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1869.

PREFACE.

The Map to which this Explanation refers was geologically surveyed by myself, in continuation of the ground represented in Sheet 14. The formations are better shown on the latter Map, and are more fully described in its Explanation, to both of which the reader is referred. At the time when this area was mapped, the work was superintended by Professor A. C. Ramsay, Local Director, under Sir Roderick I. Murchison, the Director-General.

Arch. Geikie, *Director*.

Geological Survey Office,
Edinburgh, 28*th June* 1869.

EXPLANATION OF SHEET 13.

I. AREA EMBRACED BY THE MAP.

1. The present Sheet of the one-inch Map contains merely a narrow strip of the coast-line of Ayrshire, beginning a little to the north of Girvan, and extending to Maidenhead Bay, about a mile and a half beyond Turnberry Point. The area of this marginal fragment is only about four square miles. Yet in this small compass, owing to the clear sections cut by the sea, there is not a little which is itself of interest, and which helps to explain the geology of some of the inland districts.

II. FORM OF THE GROUND.

2. Two well-marked forms of ground run along the whole length of this map. A flat platform, varying from 100 to 1200 yards in breadth, and from 20 to 30 feet above mean tide, borders the present shore. At the inner edge of this platform, a steep bank rises to the height of 100 or 120 feet above it, and then slopes away into the interior. The marginal terrace is the 25-feet raised beach, while the bluff against which it abuts marks the old coast-cliff of that period. This steep bank forms the dividing line between the two forms of ground by which the district is marked. Along its base lies the level upraised sea margin; at the top is the undulating surface of the interior. Three streams have cut valleys through this inland cliff—the Milton Burn, the Chapelton Burn, and the Lady Burn—which convey the drainage of the interior to the sea. The present shoreline at Turnberry Point, and northwards to Maidenhead Bay, is the only part which presents a series of low rocky cliffs to the waves. Elsewhere the shore is flat, and either sandy, or marked with low ledges of sandstone. To the east and south of Turnberry Point, also, a considerable depth of blown sand has accumulated, and partially obscured the platform of the raised beach.

III. GEOLOGICAL FORMATIONS CONTAINED IN THE DISTRICT.

Recent and Post-Tertiary.	Alluvium, Peat, Soils. Blown Sand. Raised Beaches. Drift Clays, Sands, Gravels, and Boulders.
Miocene (?)	Dolerite Dykes.
Middle (?) Old Red Sandstone.	Porphyrites, etc. Red Sandstones and Conglomerates.
Lower Llandovery.	Grits and Conglomerates.

IV. GEOLOGICAL STRUCTURE OF THE DISTRICT.

Lower Llandovery.

3. At the south-east corner of this Map, a small portion of Lower Llandovery rocks comes in. These consist of hard grits and conglomerates, forming part of the series which stretches from Trochraigue north-eastwards to near Dalzellolie. This district is described in the Explanation of Sheet 14.

Middle (?) Old Red Sandstone.*

4. Nearly the whole of the rocks shown on the present Map belong to this formation. They consist of red or reddish grey, sometimes yellowish, false-bedded sandstones, with occasional bands of fine conglomerates. Good sections are laid bare on the beach from the Brest Rocks southward to the Lady Burn; also in the larger water-courses. The general dip is westerly, away from the Silurian rocks on which these sandstones rest unconformably. Towards Turnberry Point, however, the dip veers round towards the north-west, to allow the sandstones to pass under a series of contemporaneous igneous rocks, which form the headland between Turnberry Bay and Maidenhead Bay.

5. The Middle Old Red Sandstone series of Ayrshire abounds in interbedded rocks of volcanic origin. Of these, an admirable example occurs in this Map, and has been laid open by the waves. It begins at Turnberry Point, where ledges of a compact greenish-coloured porphyrite dip towards the north-west, at from 10° to 15°. Similar rocks, sometimes very slaggy and amygdaloidal, succeed each other for a mile along the shore. Frequent thin courses of red and green sandstone, red marl, and sometimes even of cornstone, separate the porphyrites from each other. But the separation is further shown by the rough scoriaceous aspect which the top and bottom of the beds often assume. In many places, radiating veins occur in the porphyrite, filled up with sandstone. From the manner in which these sandstone veins are stratified, it is evident that they must have been formed by the washing of sand into open cracks in the hardened lava, before the emission of the next flow of melted rock.†

6. It has sometimes been supposed that the red sandstones of this district are later than the coal measures, and that coal may yet be found below them. This, however, is entirely a mistake. There is no carboniferous rock in this Map, and no coal-bearing strata nearer than Killochan, where the small coal-field of the Girvan begins.‡

Miocene (?)

7. Along the coast-line, a number of small dykes of dolerite occur, running in a north-westerly direction, and traversing both the red sandstones and the porphyrites. Similar dykes abound in the south and west of Scotland, increasing in numbers as they are followed westward, until

* For the reasons for considering this group of strata a middle series in the Old Red Sandstone, see Explanation of Sheet 14.

† See Explanation of Sheet 14, par. 26.

‡ See Map 14 and its Explanation.

they are found passing into and intimately associated with the great miocene volcanic plateaux of the north of Ireland and the Inner Hebrides. They are therefore regarded as probably of miocene age.*

Drift.

8. Boulder clay covers all the district inland, from the edge of the raised beach. The bluffs of the old coast-line seem to be formed mostly of this deposit; but good sections are not found here. Stiff red boulder clay may be seen on the beach opposite Dipple, crowded with its characteristic striated stones. But though no good exposure of the clay itself occurs, the beach is in many places strewed with hundreds of boulders, which have been washed out of the clay, or out of the upper parts of the drift. Most of these boulders are of grey granite, brought by the old ice-sheets from the high grounds at the head of the Girvan. Similar blocks are scattered over the inland tracts: one, which must weigh about ten tons, lies at the side of the Milton Burn, about half a mile above its mouth.

Raised Beaches.

9. There are traces here of the 40-feet beach of the west of Scotland. One of these forms the triangular terrace on which the farmhouse of Dowhill stands, near the foot of the Chapelton Burn; and again, at the bridge on the Milton Burn, there are less distinct platforms, which may mark the same old sea margin. But by much the most perfect example of a raised beach, is that already referred to as skirting the present shore along all the coast-line shown on this Map. It is the 25-feet terrace which forms such a conspicuous feature along the Scottish seaboard. There is no good section to indicate the arrangement of its component strata of sand and shingle. Its surface has been heightened irregularly by accumulations of blown sand, now covered with cultivated soil; but it forms, nevertheless, a tolerably level platform, varying, as already said, from 20 to 30 feet above mean tide-mark, and from 100 to 1200 yards in breadth. The contrast between this corn-bearing level and the steep gorse-covered bank that rises from its inner margin, is sometimes very striking, suggesting, as it does, the junction of a flat beach with the bold bluff which marks the limit of the waves.

Blown Sand, Alluvium, etc.

10. Hills of blown sand form a conspicuous feature in the north part of this strip of coast-line along the side of Turnberry Bay. Smaller areas occur as grassy hummocks along the surface of the raised beach further south.

11. Small strips of alluvium line the sides of the water-courses. The only other portion is that which lies in the hollow at Dipple, where it has been worked for brick-making. It consists of a finely laminated clay, without stones. In some of the layers, numerous plant remains occur, but no shells have been observed.

* See on this subject, *Proc. Roy. Soc.*, Edin. vol. vi. p. 71; *Brit. Assoc. Rep.*, 1867, Sect. p. 53; also Explanation to Sheet 14 of the Geol. Surv. Scot., par. 63.

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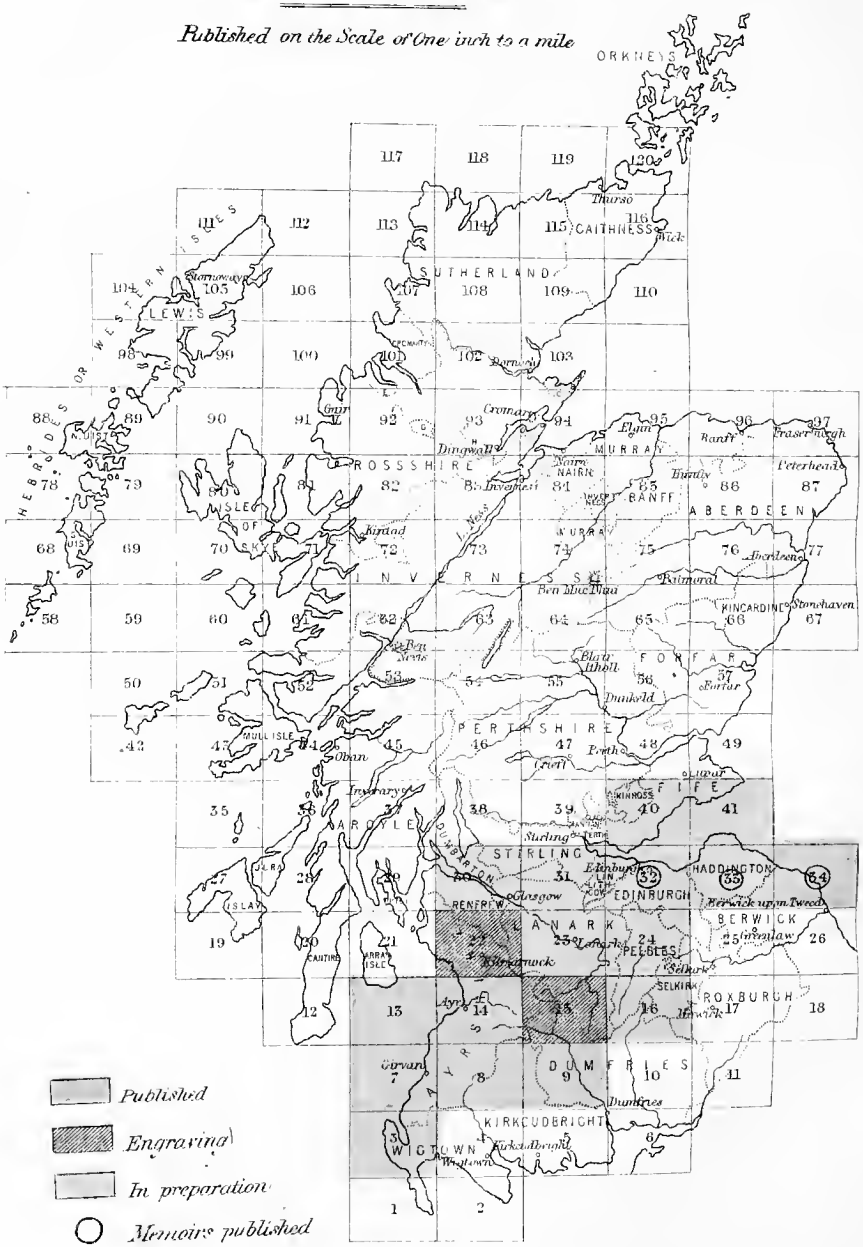

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1869.

PREFACE.

The Map of which the present pamphlet is an Explanation, has been geologically surveyed by Mr. James Geikie, Mr. B. N. Peach, and myself; Professor A. C. Ramsay being at the time Local Director of the Survey, under the Director-General, Sir Roderick Murchison. My own share of the work embraces all the ground lying to the west of a line drawn from Genoch on the Girvan Water, northward by Loch Spallander, Craigs of Kyle, Ochiltree, Catrine, and Brigland, into the adjoining sheet on the north (22). The area lying to the east of that line was mapped by Mr. James Geikie and Mr. B. N. Peach, the former taking the ground lying west and north of a line drawn from Loch Doon to Dalmellington, thence by Benbeoch, Stannery Knowe, Todhill, Fardingreoch, Coalburn, and Blackloch, to Midton, $2\frac{1}{2}$ miles S.E. from Cumnock.

In the following Explanation, Mr. James Geikie has furnished paragraphs 5, 6, 9, 19, 20, 22, 23, 44–51, 54–56; Mr. B. N. Peach has supplied Nos. 7, 8, 21, 52, and 53; the rest have been written by myself.

It is only necessary to add, that the present short description is simply intended, as its name denotes, to be an Explanation, as brief as possible, of this sheet of the Geological Survey. A much more detailed Memoir will afterwards be published on the geology of the whole of Ayrshire.

Arch. Geikie, *Director.*

Geological Survey Office,
Edinburgh, 29*th June* 1869.

EXPLANATION OF SHEET 14.

I. DISTRICTS EMBRACED IN THIS MAP.

1. The present sheet of the Geological Survey Map of Scotland embraces the greater part of the central tracts of Ayrshire, and contains an area of about 372 square miles. It includes most of the old district of Kyle, along with the northern part of Carrick. It shows the coast-line of the county from Troon to Culzean, and the valleys of the Ayr, Lugar, Doon, and Girvan rivers. Hence it embraces the coal-fields of Ayr, Coylton, Auchinleck, Cumnock, Dalmellington, and Dailly, along with the agricultural districts of which Ayr, Mayhole, Cumnock, and Mauchline are the centres.

II. FORM OF THE GROUND.

2. The greater part of the ground shown upon this Map is hilly. The highest elevations do not reach 1900 feet. They occur towards the south-east corner of the Map, where a portion of the broad uplands or table-land of the south of Scotland extends from near Dalleagles south-westward to Dailly. This strip of elevated land runs along the southern margin of the Map, and presents, for the most part, a steep face towards the north-west. From its flank the ground undulates into hill and moorland, until it sinks into the cultivated lowlands through which the Ayr, Doon, and Lugar flow. Between the valleys of the Girvan and Doon there rises the group of hills which find their highest summit in the Brown Carrick (940 feet) to the south of the town of Ayr. Separating the valleys of the Doon and Ayr runs a tract of high moorland, which, beginning at the Craigs of Kyle (800 feet), stretches south-eastward to the base of the southern uplands, and rises often into more or less detached hills, some of which exceed 1500 feet in height. The River Ayr winds through another isolated patch of hilly ground, in which it has cut a series of deep ravines, ranging from Catrine westward to Stair. On the south side of the river this group of hills sweeps in a kind of semicircle from Catrine by Ochiltree to Stair, while on the north side it is better marked in the eliptical ridge which runs from Catrine by Mauchline and Fail to Barnweil Hill, and thence by Tarbolton to Stair. A glance at the Map will show the reader that this cirque of elevated ground corresponds with the outcrop of a series of volcanic rocks, by which the Permian basin is encircled. At the north-east corner of the Map a small portion is shown of the high moorlands, which rise above Sorn, and range eastward into Lanarkshire. The lowland districts of the present Map are nearly confined to the river valleys. The largest tract lies between the lower end of the Doon and the Tarbolton heights. Another area, chiefly however occupied by peat-moss, covers the space between the Lugar and the Ayr.

III. FORMATIONS AND GROUPS OF ROCK ENTERING INTO THE STRUCTURE OF THE DISTRICT.

Aqueous.

Recent and Post-Tertiary.	Alluvium, Peat. Blown Sand. Raised Beaches.
Drift Series.	Moraine Mounds. Erratic Blocks. Sands, Gravels, and Stratified Clays. Boulder Clays.
Permian.	Red Sandstones and Volcanic rocks.
Carboniferous.	Coal Measures. Carboniferous Limestone Series. Calciferous Sandstone Series.
Old Red Sandstone.	Middle Series of sandstones, etc., and Volcanic rocks. Lower Series of sandstones, etc., and Volcanic rocks.
Lower Silurian.	Lower Llandovery. Caradoc. Llandeilo

Metamorphic.

Metamorphic Rocks in Old Red Sandstone.
Metamorphic Rocks in Lower Silurian.

Igneous.

Miocene (?)	Dolerite dykes.
Post-Permian.	Dolerite masses, intrusive.
Permian.	Porphyrites, Tuffs, Agglomerates.
Carboniferous.	Tuffs and Melaphyre veins.
Old Red Sandstone (Middle and Lower).	Porphyrites, Melaphyres, Tuffs, Felstones.
Post-Lower Silurian.	Granite and Felstone veins in Lower Silurian.

IV. GEOLOGICAL STRUCTURE OF THE DISTRICTS CONTAINED IN THE MAP.

3. On comparing the Map with what has been said (par. 2.) of the general form of the ground, it will be seen that a connection exists between the external contour and the nature of the rocks underneath,—a connection, however, which will be better understood after a detailed description of the rocks has been given. The Lower Silurian, igneous, and metamorphic rocks will be found to compose the hills, while the valleys and lowlands lie almost wholly on the softer sandstones, shales, and other members of the Carboniferous formation.

For the sake of clearness in description, the rocks will be described in geological order, beginning with the lowest; and those of each formation will be grouped under well-marked districts, for convenience of local reference.

Lower Silurian.

4. The rocks of Lower Silurian age occurring within the present Map are found in three separated districts. Of these the largest occupies the

south-east corner of the Map; the second is found flanking the great table-land to the south-west of the village of Straiton; while the third forms the now well-known hills of Craighead, Drummuck, and Mulloch, on the north side of the Girvan, near Dailly. Each of these districts falls to be described separately.

a. District of Loch Doon and Water of Deugh.

5. In this area the Lower Silurian rocks are bounded on the north-west by a large fault, which brings down against them rocks of Lower Old Red Sandstone and, in one place, of Carboniferous age. Throughout the district the Silurian formation is made up of beds of hard grey and blue greywacke, with occasional bands of dark blue and grey shales. The greywacke becomes in places gritty and conglomeratic. In such conglomeratic areas the pebbles are commonly well rounded fragments of quartz, greywacke, and grit, sometimes with angular fragments of hardened shale, from which a kind of brecciated aspect is given to the rock. The most conspicuous bed of conglomerate is found running along the northern flank of Benbrack Hill, about three miles to the east of Dalmellington. The pebbles are very large, sometimes four feet in diameter, and consist of grey granite, hornblende rock, Lydian stone, etc. Certain obscure worm-tracks (?), noticed in some of the shales in the neighbourhood of Loch Doon, are the only traces of organic life which have been detected.

6. The general strike of the beds is north-east and south-west, and the strata usually dip at high angles—the prevailing dip being to the south-east. This constant dip, however, does not give us any means for calculating the thickness of the strata, for the same beds apparently come again and again to the surface, being repeated by several folds or undulations of the strata, by which the beds are bent back upon each other. Subsequent denudation having removed the tops of the arches or curves of the strata, we have now the deceptive appearance of a great succession of beds, dipping pretty constantly in the same direction.

7. The Silurian series of this district is traversed by numerous veins or intrusive beds of pink felstone, similar to the intrusive rocks which occur elsewhere in the same strata throughout the southern uplands. These run along the strike, or from south-west to north-east. At the south-east corner of the Map a small portion of granite is shown. It forms part of the large mass of which the Cairnsmore of Carsphairn (2612 feet) consists. The granite is grey and fine grained, and sends veins into the surrounding greywacke and shale. These are much altered for some distance, assuming a crystalline or schistose character.

8. Two veins of galena were once worked at Dalleagles. They occur in the Silurian rocks, and run in a north-west and south-east direction across the strike of the beds, until they are cut off by the large fault bounding the Silurian uplands. A hematite vein has been opened along the surface, in the bed of the Muck Water. It is thin and unequal, and has never been worked. It runs across the strike of the Silurian rocks, but does not appear to enter the Old Red Sandstone.

b. District of Straiton and Glenalla.

9. A long band of conglomerate occurs between the Water of Girvan at Genoch and the head of the Dalcairney Burn. It is bounded on the north-west by a fault which lets down strata of Middle (?) Old Red Sandstone age, and on the south by another fault, bringing in igneous rocks belonging to the Lower Old Red Sandstone. This is a well-marked and characteristic conglomerate. It has the greenish colour so conspicuous

in the Silurian conglomerates to the south-west, and contains pebbles of altered rocks. The greenish matrix is sometimes hardened, but commonly is soft, pulverulent, and earthy. In some places indeed the rock is quite an uncompacted gravel. Courses of pebbly grit occasionally traverse the conglomerate, and sometimes it consists of alternations of green grit with lines of stones. Occasionally the conglomerate is a mere pell-mell assemblage of stones, with very confused or no stratification. All the stones are well rounded and water-worn.*

10. From the village of Straiton, as far as the hills overlooking Kilkerran, there runs along the northern flank of the upland country an irregular strip of Silurian strata. The exact subdivision of the Silurian series to which these strata belong has not yet been fixed. They have a much less ancient aspect than the strata just described. Fossils have indeed been obtained from them, but not yet sufficiently well marked to indicate how far the strata on this side of the Girvan correspond with those on the north side. The best sections are to be seen in the streams to the south-west of Straiton, on the roadside near Kirkbride, in the Shiel Burn, at and below Drumyork, and between that stream and the farmhouse of Blair. From these sections the strata are seen to consist of green, grey, yellow, and sometimes red shales, with bands of greywacke, which increase in number and dimensions towards the east, where they become coarse gritty flagstones, sometimes conglomeratic. The strike remains persistently in a north-easterly line, the beds being inclined at high angles usually to the south-east, sometimes to the north-west, but often quite vertical. Some confusion occurs in the Shiel Burn, above Drumyork, at the junction of this shale and greywacke series with the grits and flagstones of the Old Red Sandstone; and further east a similar difficulty occurs in drawing a line between the two formations. This appears to be due partly to faulting and partly to a metamorphism which, affecting both the Silurian and Old Red Sandstone, has given rise to a further resemblance between strata probably to some extent originally similar, and has produced crystalline masses in each of the formations. (See pars. 14 and 32.)

c. District of Craighead, Drummuck, and Threave.

11. It will be observed from the Map that a band of Lower Silurian rocks extends along the north bank of the Girvan from Craighead to Dalzellolie. The abundantly fossiliferous nature of this band, first made known by Sir Roderick Murchison,† has furnished a means of subdividing the rocks according to the received Lower Silurian classification. The subjoined table shows the succession in downward order.

Lower Llandovery.	3. Yellow and reddish brown, highly fossiliferous sandstones and grits, yellow, blue, and grey shales and grits.
	2. Bands of conglomerate, sometimes very coarse.
Caradoc.	1. Grey and brown mudstones, hard grey grits, shales, a thick bed of limestone, with conglomerate and shale.

12. These strata are disposed in an anticlinal form. On the north-west side they are uncomformably overlaid with the Middle (?) Old Red Sandstone. On the south-east they are cut off by a fault which brings down against them the Carboniferous rocks of the Girvan valley; but the

* This conglomerate is a north-eastern prolongation of the massive green conglomerates which are associated with the Caradoc limestones of the Stinchar and Assel valleys, to be described in a future memoir.—A. G.

† *Quart. Journ. Geol. Soc.*, vol. vii. p. 153.

axis of the arch is well seen on the flanks of the Quarrel Hill above Dalquharran.

13. *Caradoc.*—Owing to the depth of drift and other causes, it has not been possible properly to subdivide this group. The limestone occurs in several lenticular patches along the southern margin of the Caradoc area; and as that area is formed of an anticlinal axis, the limestone might be supposed to lie rather high in the series. This may indeed be its position, though at present no conclusive evidence has been obtained on the subject. The largest mass of limestone has long been worked at the well-known lime quarry of Craighead. It is a white or greyish compact rock, sometimes green from diffused serpentine. At one place it contains some green shale dipping towards the east, and thus indicating the bedding of the limestone, which is otherwise an amorphous fractured mass. On the west side of the quarry a coarse serpentinous conglomerate appears, while beyond this a dirty green serpentinous rock of metamorphic origin occupies the rest of Craighead Hill. A small patch of the limestone, enclosed on all sides save the south by this metamorphic rock, lies in the wood in the steep slope to the south-west of the quarry. Again, a similar limestone, but in a much thinner bed, stretches from a cot called Thunderton Hall, eastwards to the farmhouse of Glenlochrie. It is associated with a metamorphic rock similar to that of Craighead Hill, and at the quarry near Glenlochrie it is seen to be bedded in vertical conglomerates.

14. The rock of which Craighead Hill is formed, changes its aspect so rapidly as it is followed over the ground, that it cannot easily be classed under one name. In some places, as near Killochan, it is a serpentine; in other places it resembles a fine-grained decomposing diabase. Its more prevalent character is that of a dull, dirty-green, shattery rock, of which a fresh fracture can scarcely be obtained, full of diffused serpentinous matter, often veined with carbonate of lime, having sometimes quite the aspect of a decayed greywacke, and always more or less decomposed. It appears to represent a portion of the Caradoc strata which has undergone metamorphism. It resembles rocks which occur in a similar way among the greywacke and limestone to the south of the Girvan district. Another small patch of the same kind of rock has been referred to above as occurring to the east of Craighead quarry.

*Characteristic Fossils from the Craighead Limestone.**

Petraia elongata.	Leptæna transversalis.
Palæopora favosa.	Orthis biforata.
Stenopora fibrosa.	,, calligramma.
Favosites aspera.	,, vespertilio.
Crinoid stems (fragments).	Maclurea Logani?
Encrinurus punctatus.	Raphistoma lenticularis.

15. The best sections of the mudstones of the Caradoc series are those laid open in the channel of the Lady Burn (or Drummuck Burn), above the farmhouse of Drummuck. Good sections are also exposed in the streams which descend from the east and south sides of Quarrel Hill. The Lady Burn sections are the chief repositories of fossils.

Characteristic Fossils from the Lady Burn (Drummuck) Section.

Ampyx rostratus.	Theca triangularis.
Calymene Blumenbachii.	Bellerophon acutus.
Trinucleus seticornis.	,, carinatus.

* In this and the succeeding fossil-lists (furnished by Mr. Etheridge, Palæontologist of the Geological Survey), only some of the more characteristic forms are given. The full lists will be given in the subsequent extended Memoir.

16. *Lower Llandovery.*—No unconformability has satisfactorily been traced between the Caradoc rocks just described and the overlying strata which are now to be noticed. But the occurrence of a massive conglomerate between the two series may possibly indicate a break in the succession of deposits. This conglomerate may be followed as a continuous band of variable thickness along the base of the Llandovery group, forming often a marked ridge or succession of ridges, owing to its great compactness. It is thickest towards the south-west, where it covers a considerable space at Trochraigue. At the north-eastern end it is seen to bend round the anticlinal axis, and to thin away southwards. Beds of grit and sandstone are interstratified with the conglomerate. This is particularly well shown on the north side of the Quarrel Hill, where the conglomerate, by a series of intercalations of flagstones, passes conformably up into the Llandovery rocks of the Kirk Hill.

17. The strata into which the conglomerate thus graduates upwards are reddish brown or yellow flagstones, sandstones, and grits, which pass upward into blue grits, and blue, grey, and yellow shales, sometimes with conglomerate bands. The lower parts of this series are best shown in the numerous openings which have been made along the road between Quarrel and Kirk Hills, to the north of the farm of High Mains or Mullock, and in the quarry near Rough Neuk. The higher parts seen in this area are exposed in the courses of the brooks to the north and east of Rough Neuk.

Characteristic Fossils from the Lower Llandovery Rocks of Kirk Hill.

Petraia elongata.	Orthis calligramma.
Heliolites interstinctus.	Orthisina Scotica.
Nidulites favus.	Macrocheilus elongatus.
Hemithyris hemisphærica.	Murchisonia cancellata.

Old Red Sandstone.

18. Between the Silurian rocks and the lowest members of the Carboniferous system, there occurs in Ayrshire a great series of sandstones, flagstones, and conglomerates, with masses of interbedded rocks of volcanic origin. These belong to two distinct groups. Of the one, the chief area on the present Map ranges along the north-west side of the Silurian uplands. It lies on the same line of strike as the rocks of Corsincone, which, ranging north-eastward into Lanarkshire, are undoubtedly of Lower Old Red Sandstone age, and which the Ayrshire series closely resembles. It has been judged advisable, therefore, to class that Ayrshire series provisionally with the Lower Old Red Sandstone. The second group lies unconformably on the first, as well as on the Llandovery rocks, and is covered unconformably by the lowest member of the Carboniferous series. It is classed, in the meantime, as a Middle (?) Old Red Sandstone, though we have no means at present of determining how far it represents the true Middle Old Red Sandstone of the north of Scotland. Possibly it may prove, in the end, to be merely an unconformable upper part of the great lower division of that formation. Each of these groups contains an abundant suite of contemporaneous volcanic rocks; and in each of them, but more particularly in the lower group, there are proofs of considerable metamorphism.

1. Lower.

a. Dalmellington District.

19. The Lower Old Red Sandstone is represented in this district by a long narrow strip of igneous and aqueous rocks running along the flanks

of the great Silurian uplands. This narrow band is bounded on all sides by faults—the great north-east and south-west fault separating it from the hilly region to the south, while various faults on the north and north-west bring it successively in contact with coal measures and Carboniferous limestone, and with rocks of Caradoc age. The rocks of this district consist of conglomerates, shales, and hardened mudstones, which are associated and interbedded with various porphyrites. Intrusive felstones and mica-traps cut through these rocks in all directions; while, as just mentioned, certain portions of the aqueous strata have undergone some degree of metamorphism. The strike of the beds is north-east and south-west. To the south-west of Dalmellington the dip is either vertical, or nearly so, while between that village and Dalleagles the beds are commonly inclined at high angles towards the south-east.

20. The conglomerates are made up chiefly of well-rounded fragments of grit, greywacke, felspathic sandstone, compact crystalline felspathic rocks, Lydian stone, quartz, etc. They are usually rudely stratified. The other rocks of aqueous origin are shales and felspathic mudstones. These are generally much jointed and shattery, and have often become highly indurated. In the neighbourhood of Knockdon the conglomerates begin to show traces of metamorphic action, which is better exemplified, however, in the rocks south of the Water of Girvan; but as these are not embraced in this Map, they fall to be described in the Explanation to accompany Sheet 8. At Knockdon, however, it may be mentioned that the conglomerates are highly altered, the matrix frequently assuming a crystalline aspect even in places where the pebbles are not obliterated. Near Knockdon, copper is said to have been once partially worked.

21. In the district between Dalmellington and Dalleagles, as just mentioned, the Old Red Sandstone series is steeply inclined towards the south-east: hence the highest visible beds are those next the Silurian uplands, while the lowest lie next to the coal-field. This grouping is prolonged towards the north-east into Lanarkshire, where a much more complete development of the formation, both of its aqueous and igneous rocks, is to be found.

22. The contemporaneous igneous rocks consist of various porphyrites. These are either dark purplish, dull, fine-grained, amygdaloidal, porphyritic rocks, or they are of a lighter bluish colour, less earthy, and more crystalline texture, and not so conspicuously amygdaloidal, nor so coarsely porphyritic, as the darker purplish porphyrites sometimes become. Between these varieties, however, there are many gradations, some of the finer-grained, dull, brown rocks being with difficulty distinguished from indurated felspathic mudstones. The intrusive rocks present many features of interest. The most common variety is a pale or dark pink felstone, which often becomes highly micaceous. When the intrusive mass comes in contact with conglomerate, the latter is often highly altered, and the junction between the two rocks is frequently much confused, the conglomerate being caught up and enclosed in the felstone. These phenomena may be well studied on the hills looking down upon Wee Berbeth Loch, about half a mile from the River Doon.

None of the streams in this neighbourhood afford good sections; but the beds are often well exposed along the bare, rocky hill sides, which are singularly free from drift.

b. Sorn District.

23. The Old Red Sandstone of this district forms the somewhat conspicuous hill of Blacksidend, which sweeps up from the valley of the River Ayr at Sorn. Only a small portion of this area of Old Red Sand-

stone comes into the present Map, and the rocks will therefore be more particularly referred to in the Explanations accompanying Sheets 22 and 23. The strata here are bounded on the west and south by faults, which bring down against them rocks of Carboniferous age. In Auchinlongford Burn they appear to be covered unconformably by the Calciferous Sandstone series. The strata consist chiefly of grey and pinkish grey felspathic sandstones and flagstones, which at Lanfine (Sheet 22) have yielded remains of *Cephalaspis Lyellii*. They exhibit considerable metamorphism in some places, the rocks becoming quite crystalline. This may be seen at Tincorn Hill. Farther north (Sheet 22), however, the metamorphism becomes more intense, the strata passing into minette, granite, etc.

2. Middle (?)

24. This group occupies two separated districts on the present Map. One of these lies between the lower course of the Doon and the Girvan Water, and may be called the Kirkoswald, Maybole, and Brown Carrick district; the other stretches as a band of hilly ground from near Dalmellington to the south-west of Straiton, and may be named the Straiton and Dalmellington district. The group contains the following rocks in descending order:—

5. Reddish micaceous sandstones, with *Pterichthys major*.
4. Beds of porphyrite, with thin layers of tuff, and lenticular seams of sandstone and conglomerate.
3. A very thick series of purple, reddish or greenish sandstones and flagstones, with beds of porphyrite, tuff, and conglomerate intercalated at different horizons. These volcanic rocks increase in importance, when followed in descending section, until they become
2. A group of porphyrites locally developed to a great thickness, and resting upon
1. Reddish and greenish sandstones and conglomerates.

a. Kirkoswald, Maybole, and Brown Carrick District.

25. This area extends along the coast-line of Ayrshire from the mouth of the Girvan Water to the Heads of Ayr, and inland a little beyond Kirkmichael, thus occupying pretty nearly the angle formed by the Girvan and the Doon. It contains the best development of the Middle (?) Old Red Sandstone to be found in the county. Beginning at the south, at the margin of the Llandovery area already described, we find the members of this middle group dipping towards the north or north north-west, at angles ranging from 5° to 25° or more. The same dip continues, with hardly any interruption, to the Heads of Ayr—a distance of eight miles. If we allow an average angle of only 8°, and lay aside the effect of any concealed faulting, we obtain a thickness of 6000 feet for this group in the district now under description.

26. Good sections of the lower sandstones and flagstones are seen in the streams between Kirkoswald and the Vale of Girvan, more especially in the Chapelton Burn. The volcanic rocks associated with this part of the group form conspicuous hills between Maybole and Dailly. They consist of yellow or pinkish porphyrites and dark compact melaphyres, forming beds interstratified with the sandstones and conglomerates. Higher in the series come the sandstones of Maybole, well seen in the quarries there. These beds are succeeded towards the north-west by others which contain a large admixture of felspathic material, and indeed sometimes pass into a kind of coarse sandy tuff. Of this nature is the zone of rock which forms the greater part of Mochrum Hill (there

containing also a bed of porphyrite), and which stretches thence, north-eastward, by Bogside and Brockloch. Westward, a still more copious development of volcanic rocks forms the range of cliffs at Culzean. The sea has there laid bare a succession of different porphyrites in beds which dip at low angles towards the north, and are sometimes separated from each other by thin courses of sandstone, shale, conglomerate, or even cornstone. These porphyrites are for the most part dark green or purple, finely crystalline, sometimes strongly porphyritic, and often amygdaloidal. Here, as well as throughout the porphyrites of this group, irregular vertical veins of sandstone sometimes traverse the rock in a stellar arrangement. The sandstone is horizontally stratified, and agrees in character with the sandstone lying between the porphyrites; whence it appears that these veins are due to the sand which was washed into the irregular star-shaped cracks of the cooled lava, before that lava was covered by the next stream of molten matter.*

27. From the Culzean porphyrites, northwards, the coast-line affords a good section of the overlying sandstones. These agree in character with those which stretch inland; they are cut into ravines by the streams between Brockloch and Auchendrane. Here and there they contain bands of conglomerate; but their common character is that of flaggy or false-bedded red, yellow, greenish, or purplish grey sandstones.

28. The next member in ascending order is the series of porphyrites which forms the range of high grounds between the Heads of Ayr and Maybole, rising to a height of 940 feet above the sea. The bedded character of these rocks is well shown, even at a distance, by the succession of low escarpments or terraces looking towards the south south-east, and of gentle slopes in the opposite direction. It is further marked by the intercalation of occasional short and inconstant courses of sandstone, shale, and marl between the sheets of porphyrite. The prevailing rock, as at Culzean, is a dark close-grained porphyrite, varying in tint from a dull purple to a dirty green, but sometimes assuming brighter shades, usually finely porphyritic, and often highly amygdaloidal. The best sections are of course those of the cliffs to the south of the Heads of Ayr; but sections are to be seen in almost every part of the area covered by these rocks.

29. Where the porphyrite series ends on the shore near the Heads of Ayr, there is some obscurity in the order of succession, owing to a number of faults and dolerite dykes. A red tuff, and some red micaceous flagstones, are seen on the beach, dipping away from the porphyrite. Here specimens of *pterichthys major* have been obtained. Beyond these disturbed beds lie the nearly horizontal red sandstones, which lie at the base of the Carboniferous series, the line of junction between the two formations being probably a fault. No further trace of the Old Red Sandstone is to be met with to the north; and the beds just described form the highest parts of that formation which have yet been found in Ayrshire.

b. Straiton and Dalmellington District.

30. From the neighbourhood of Dalmellington, for fully fifteen miles to the south-west, there is a strip of hilly ground which fronts the great Silurian uplands, of which indeed it may be considered as a kind of outwork. It is geologically marked off, however, by being mainly occupied by members of the Middle Old Red Sandstone series, though in many places portions of the lower group of that formation, as well as different parts of the Lower Silurian series, appear. It will be seen from the Map (which, however, contains only a portion of the area, the rest being embraced by Sheet 8) that the structure of this district is somewhat complicated.

* See Explanation of Sheet 13, par. 5.

Both the Silurian and Lower Old Red Sandstone formation had been here much disturbed before the deposition of the Middle Old Red Sandstone. The latter series has been subsequently fractured, invaded by masses of intrusive felstone, and in some places changed into crystalline rocks. In spite of these causes of obscurity, however, it is evident that we have here an unconformable group of strata, identical in character and in geological relations with those which occupy the Kirkoswald, Maybole, and Brown Carrick district.

31. That portion of the series which is shown on the present Map consists of a thick series of reddish, greenish, and sometimes yellowish sandstones or flagstones, often gritty or pebbly, and green or reddish conglomerates, the whole passing under a massive group of porphyrites, like those of the Brown Carrick Hills. The sandstones and conglomerates are seen in greatest thickness in the streams which fall into the Girvan a few miles to the south of Straiton,—particularly the Balbeg Burn, the Palmullan Burn and its tributaries, and the Genoch Burn. But in this district the hill sides are for the most part so bare of drift, that sections of the rocks are everywhere abundant along the slopes. A marked stratum at the top of the series is a coarse red, green, or yellowish conglomerate, which has been traced for several miles along the foot of the porphyrite escarpment. No fossils have yet been found among any of these rocks.

32. The most marked example of metamorphism met with in this group occurs in the Black Hill of Knockgardner, about two miles to the south-west of Straiton, where the felspathic sandstones pass into crystalline porphyritic rocks, which in places become diorites. Three separate areas of metamorphism occur here: two in the Middle Old Red Sandstone series, and one among the Silurian rocks. The latter forms the Green Hill of Knockgardner, where a pinkish grey compact rock passes into a quartziferous porphyry, while the shales in the neighbourhood are much altered. Large masses of a pink or yellow intrusive porphyritic felstone traverse the Middle Old Red Sandstone series of this district. Of these, the largest lies to the south-west of Straiton, and includes the conspicuous hill of Glenalla (1406 feet) while other masses occur near Dalmellington.

33. The porphyrites which overlie the sandstone series form a marked group of hills to the south and south-east of Straiton. Where their lower limit is exposed without faulting, they form an escarpment which runs as a bold feature along the summit of the sandstone slopes. Their bedded character is likewise indicated by the terraced outline of the hills, as in the case of the Brown Carrick Hills already noticed. These porphyrites agree in petrological character with those of the other Middle (?) Old Red Sandstone district of this county. They are usually fine-grained, and dark in colour, the tint ranging from a bluish grey, through various shades of purple and red, to a dirty brown. Usually they are more or less porphyritic—sometimes strongly so—while the upper and under portions of the beds tend to assume an amygdaloidal character. The same veinings of sandstone, and thin intercalations of conglomerates, sandstones, etc. occur which were referred to in pars. 26, 28. No strata are found resting on these volcanic rocks, which form the highest members of the group visible in this district. A reference to the Map will show how much the group has here suffered from the effects of faults, especially towards the eastern end of the area.

Carboniferous.

34. This great formation covers by much the largest part of the county of Ayr. There being no Upper Old Red Sandstone here into which it

might graduate downward, it rests unconformably upon all the older formations. Its upper member is overlaid unconformably with the Permian rocks. In this way neither the true base nor summit of the Carboniferous series of Ayrshire can now be seen. The formation consists of the following groups, in descending order :—

Sign on Map.	Groups of Strata.	Localities.
d 5.	Coal Measures, consisting of—	
	b. Red sandstones, fireclays and marls, with carboniferous plants, and a seam of limestone containing *spirorbis carbonarius.* No workable coal-seams in this group.	Monkton, Auchencruive, Annbank ; Coylton Water below Coylton ; from Craigs of Kyle to Auchenleck ; ravines of Lugar near Ochiltree, and of the Ayr at Catrine ; coal-fields of Ayr, Coylton, Dalmellington, Cumnock, Auchenleck, Lugar, and Sorn.
	a. A thick group of white and grey sandstones, dark shales, fireclays, ironstones, and coal-seams.	
d 2.	Carboniferous Limestone Series.	
	A suite of sandstones, shales, and limestones, with seams of coal.	Girvan coal-field, Craigs of Kyle, Patna, Keirs ; road from Dalmellington to Cumnock, near Old Cumnock, Sorn.
d 1.	Calciferous Sandstone Series, consisting of—	
	b. A variable group of white sandstones, cement-stones, and marls, below which lies	Dailly ; coast between mouth of Doon and Brackenbrae ; between Ayr and Martnaham Loch ; neighbourhood of Sorn ; Kilkerran ; Girvan Water below Straiton ; moors north of Straiton ; River Doon from Patna to the sea.
	a. A group of red sandstones, marls, and cornstones.	

It will be at present most convenient to divide the carboniferous area into districts, and to describe the different members of the formation which these districts contain.

a. District of the Vale of Girvan.

35. In this district are included all the carboniferous rocks which extend from Dailly to the limestones of Patna and Keirs. The lowest group of strata consists of red and reddish or purplish grey sandstones, marls, with bands of cornstone and coarse sandy limestone, forming the lower division of the Calciferous Sandstone series. These strata are well seen in the Lady Glen of Kilkerran, where their base rests unconformably upon the Silurian rocks. Good sections are likewise exposed in the other streams which descend from the hills, on the south side of the Girvan valley, as well as in the course of the Girvan Water itself, between Kirkmichael and Straiton, and in the water-courses between this part of that stream and the valley of the Doon. The limestones are laid open in quarries at Lannielane, Kirkbride, Todglen, Balgreggan, and to the east of Kirkmichael. Fossils are scarce throughout this group of strata. Plant remains occasionally occur; also worm-burrows and surfaces showing ripple-marks.

36. This red sandstone group, as indicated on the Map, has been in great measure cut off along the north side of the Girvan valley by a large fault. On the south side, however, it is largely developed, and it spreads eastward over the moorlands up to the valley of the Doon. It there passes under the carboniferous limestone series, though in some localities, as at the Meikleholm Burn, there are indications of the intermediate cement-stone group, which elsewhere separates the red sandstones from the carboniferous limestone.

37. Above the red sandstones comes a group of white or grey sandstones, blue or grey marls, shales, and cement-stones. It is seen in the

lower portions of the streams near Dailly, but is not so well developed here as in the district of the Doon. It is liable to great changes in its extension over the county, being in some places several hundred feet thick, while in others, and at a short distance, it is entirely absent.

38. *Girvan Coal-field.*—Overlying the cement-stone group, comes the Carboniferous Limestone series, stretching along the north-west side of the Girvan valley from near Craighead to beyond Dalzellolie. The following table shows the succession of the chief strata in descending order:—

Sandstones, shales, and fireclays, with thin coals and limestones (not yet wholly proved); thickness probably from	450 to 500	feet.	
Dalquharran Limestone,	2	„	6 inches.
Strata, chiefly Yellow Sandstone,	102	„	
Main Coal,	7	„	
Fireclay,	2	„	
Ground Coal,	3	„	
Strata,	3	„	6 „
Little Coal,	4	„	
Strata,	12	„	
Parrot Coal,	6	„	
Strata,	10	„	
Coral Coal,	5	„	8 „
Strata,	18	„	
Craigie Coal,	8	„	6 „
Strata,	30	„	
Rotten Coal,	6	„	
Strata,	about 60 or 70	„	
Captain's Bridge Limestone,	27	„	
Sandstones, Shales, Fireclays, etc.			

In this small coal-field there are in all fully forty feet of workable coal. The strata overlying the Dalquharran limestone are at present being sunk through, with the view of reaching the Main coal in the centre of the field. When the new pit is completed, a section will be obtained of the whole of the strata contained in this coal-field. As shown on the Map, there is here a basin-shaped arrangement of the rocks; the coals and limestones dip into a long trough from the south-east side, and rise again to the surface on the north-west side.

Detailed Map of this Coal-field.—The effects of the faults by which the field is traversed, as well as the detailed outcrops of the different seams, are given on Sheet No. 50 of the 6-inch Geological Survey Map of Ayrshire.

b. Lower District of the Doon.

39. In this district is embraced the Calciferous Sandstone group, which is developed between the limestones and coals of Patna and the shores of the Firth of Clyde at and south of the mouth of the Doon. The lower or red sandstone series is copiously displayed here, particularly along the course of the River Doon, from Cambusdoon to near Auchendrane. It is also well shown in some of the ravines of the same river above Dalrymple, and in the shore-cliffs immediately south of the Heads of Ayr. In a quarry near Kersepark, south of the Craigs of Kyle, the red sandstones contain well-preserved remains of *lepidodendron*, and other carboniferous plants. But fossils are remarkably scarce. This group of strata rests unconfor-

mably upon the Middle (?) Old Red Sandstone, the beds of which have their edges overlapped by it as far south as Barnshean Loch, where it is thrown down against the older formation by the great Girvan fault already referred to. It passes upward into the cement-stone group. The latter group of strata reaches a considerable thickness in this district. The best sections are those on the beach between the mouth of the Doon and the Heads of Ayr. But inland the exposures are few, owing to the depth of drift with which the district is covered. The position and thickness of the series, however, is shown by a number of borings (one of which, near Macnairston, passed down through 330 feet without reaching the bottom), and also by numerous old filled-up quarry-holes and ruinous limekilns, which mark where the more calcareous beds were formerly burnt for lime. As exposed on the shore section, the series consists of numerous alternations of grey, green, and blue shales or argillaceous marls, white or grey sandstones, and ferruginous limestones or cement-stones. Some of these strata abound in organic remains, as cypridcases, fish-scales, and plants. At Greenan Castle, and at the Heads of Ayr, dolerite-tuff occurs. At the former locality, the tuff is seen on the beach to be both distinctly interbedded with the cement-stone group, and to break through it intrusively. We have there probably a part of the neck or orifice of ejection, as well as a portion of the ash which was thrown out and stratified among the sandstones and shales. At the Heads of Ayr the tuff is either coarse and unstratified, or its bedding is confused or pitched at high angles, while the stratified rocks which adjoin it dip into it, and are much broken, or have the edges of their beds truncated sharply by the tuff. These appearances are similar to these presented by the tuffs of Dunbar and the Fife coast. They serve to mark what was probably a focus of eruption. The Heads of Ayr would therefore represent the 'neck' or vent of a volcano which was active during the period of the calciferous sandstones. The coast section likewise furnishes some excellent examples of dolerite dykes; but these belong to a much later period (see par. 63).

c. The Ayr Coal-field.

40. Under this title is here included the district which extends along the coast from Ayr to Troon, and stretches inland to the foot of the Tarbolton Hills, Stair, Drongan, and the southern extremity of the Craigs of Kyle. There is here a great development of carboniferous rocks, extending from the Carboniferous Limestone series up to the Permian formation. The limestone series is, however, but ill represented. It may be seen on the south-west side of the Craigs of Kyle, where one of the limestones has been quarried. It has likewise been met with in bores to the north-west of these Craigs; but from that point onward to the sea no exposure of limestone can be seen at the surface. Indeed no evidence has been obtained as to whether the limestone series really exists between Loch Martnaham and the sea. If it does, it must be exceedingly thin. In default of any proof of the presence of this series here, a dotted line has been drawn on the Map along the doubtful ground, and the coal measures have been shaded into the calciferous sandstones.

41. Numerous natural sections of the Coal Measures are furnished by the different water-courses of the district. The lower parts of the series are well seen in the Coylton Water, at and below Sundrum. The same stream, between Sundrum and Garrochhead, flows over all the coals, and a part of the overlying barren red measures. Good sections are likewise laid open along the course of the River Ayr at Cameronsholm and above Auchencruive. The following table shows the position and average thicknesses of the principal coals in the district:—

Red Sandstone Series.	
Light Sandstones, Shales, Fireclays, and thin Coal,	60 to 70 feet.
Ell Coal,	3 feet 4 inches.
Strata,	78 feet.
Crawfordston Coal,	8 „
Strata,	30 to 60 „
Ayr Soft, or Five-feet, or Three-dirt Coal,	5 to 7 „
Strata,	150 „
Ayr Hard or Splint Coal,	4 „
Strata,	300 „
Black-band Ironstone,	1 „
Strata,	120 „
Uppermost Limestone.	

The black-band ironstone in this table is the same as the Burnfoot seam of Dalmellington, but it is not well seen in the Ayr and Coylton district. Its position has been found in borings to the south-west of Coylton, but the seam is not worked there. The best of the coal seams is the Ayr Hard Coal, long worked at Ayr and the neighbourhood, but now exhausted in that part of the field. The higher seams are found in the eastern half of the district; but as they are traced seawards, their position becomes uncertain, owing to the want of natural sections, and to the number of faults and igneous rocks by which the results obtained from borings are much obscured. It is quite possible, however, that a large area of workable coal may yet be found to exist to the north and north-east of Ayr. The upper barren red measures do not lie quite comformably upon the coal-bearing series; and a more systematic series of deeper bores might reveal the existence of a new coal-field between Ayr and the Dundonald Hills. There can at least be no doubt that the true coal-bearing series underlies the red sandstones throughout that district. Whether or not the coal seams would be found in such a state as to form a profitable working, could only be learnt by proper borings.

42. The upper red sandstone group, to which reference has just been made, forms the highest group of carboniferous strata in Ayrshire. The Map shows how these rocks occupy the central part of the county, and are overlaid with the Permian basin. They consist of red, and reddish or purplish grey sandstones, red, purple, or lilac clays and shales, and an occasional but inconstant thin band of fine white limestone. Coal-measure plants occur in some of the argillaceous beds, and the *microconchus carbonarius* occurs in the limestone. A section of a portion of the series has been cut by the Coylton Water below Coylton, but the best sections are those of the River Ayr, between Sorn and Ballochmyle, where the alternating red sandstones, clays, and shales, with plants, are well seen, and where the limestone is better developed than at any other place in the county. This group of rocks, when mapped out in detail, is found not to rest always on the same horizon of the coal-bearing measures below, but to steal across or overlap them. This is particularly observable to the east of the Permian basin, where the upper red sandstones come to lie directly upon the carboniferous limestone.

43. The Ayr and Coylton coal-field, like the other coal-fields of Ayrshire, is traversed by numerous faults, and by masses of igneous rock, whereby the coal seams are more or less destroyed. The prevailing direction of the faults is from W.N.W. to E.S.E. None of them have a great throw, few exceed 20 or 25 fathoms, and the majority are only a few feet. There is a belief in the district that a 60-fathom fault runs in the usual direction from Auchencrnive to the shore at Kincase, near Prestwick, and that no workable coal exists to the north of it. There does

not appear, however, to be any good foundation for this supposition. A coal, believed to be the Splint or Hard Coal of Ayr, has been found in several bores between Prestwick and Kincase, at depths varying from 28 to 45 fathoms. If there be any fault along the line just mentioned, it does not throw out the coals, nor sink them to a great depth on the north side. The practicability of working the coals does not depend upon the existence of this fault, but on the quality and extent of the seams themselves; and for this information, further borings are necessary.

44. The igneous rocks occur in the form of dykes and intruded masses of dolerite. These are of at least two ages. The older series consists of sheets of dolerite overlying or injected between the strata of the coal-field. The largest mass of this kind in the district forms the conspicuous eminence of the Craigs of Kyle. Another considerable area of dolerite overlies the coals at Auchencruive, and other patches are seen higher up the Ayr, south of Enterkine and Stair, where a thick series of pale grey shales has apparently been hardened by the heated masses, so as to form the well-known whetstones or Water-of-Ayr stones. The dolerite dykes belong as a whole to a much later period. In the Ayr, at Auchencruive, one of them may be seen cutting the older dolerite. They form part of a series which spreads over the whole of the west of Scotland, and which is further described in par. 63.

Detailed Maps of this Coal-field.—The detailed structure of this coal-field is shown upon the published Maps of the Geological Survey, on the scale of six inches to a mile—viz. Sheets 27, 33, 34, and 40 of the 6-inch Map of Ayrshire.

d. The Dalmellington Coal-field.

45. The Dalmellington coal-field is bounded on the north-west by the Calciferous Sandstone series, and on the south-east by rocks of Lower Old Red Sandstone age, against which it is thrown by several powerful faults. On the south-west it reposes conformably on the calciferous sandstones, and stretches away to the north-east until it verges with the coal-fields of New Cumnock and Cumnock. The bottom beds of this coal-field belong to the Carboniferous Limestone series, which is here of inconsiderable thickness. Upon the top of the limestone series come the true coal measures, which again are covered unconformably by the upper barren red measures already described. The millstone grit is thus unrepresented, unless it be by some sandstones lying at the base of the coal measures.

46. The lowest bed of limestone in the Carboniferous Limestone series is that worked at Patna. It contains *productus giganteus*, and other characteristic fossils. About 50 fathoms higher in the series occur three and sometimes four limestones, separated from each other by a few fathoms of intervening sandstones and shales. They are seen at Keirs and Drumgrange near Waterside, and at Coalston near Patna. In Grimmet Burn and Glenhead Burn thin impure limestones also appear. The whole thickness of the limestone series in this district does not exceed 360 feet. But no good continuous section of the series is exposed, and the little that can be seen is much confused by the numerous dislocations which traverse the district. Only one coal is worked in this series—viz. the Patna coal. In some pits this coal is split up by intervening strata into two, and even as many as four seams. When all these come together so as to form one seam, the coal is as much as 14 feet in thickness.

47. In the overlying Coal Measures three coal seams have been worked: the Minnivey, the Chalmerston, and Sillyhole coal seams. But the principal mineral of the district is the Burnfoot black-band ironstone. This valuable seam is 2 feet 3 inches thick in the Waterside workings; but as

it passes eastward it thins out, till in the New Cumnock coal-field it is often not 2 inches thick. It is believed to be the same seam as the black-band of Auchinleck and Lugar. Besides this seam of ironstone, there is a thinner black-band ironstone, worked for a time at Craigmark, Dalmellington, but it was found to pass eastwards into a gas coal.

The general succession and thickness of the principal seams in the Dalmellington field is as follows:—

	Fms.	ft.	in.
Craigmack Black-band Ironstone,	0	0	10
Strata,	47	0	0
Sillyhole Coal,	0	5	6
Strata,	50	0	0
Chalmerston Coal,	0	4	0
Strata,	10	0	0
Minnivey Coal,	0	3	6
Strata,	109	0	0
Burnfoot Black-band,	0	2	3

Besides these coal seams, there are others which may yet come to be available. Fireclay is also worked in this district.

48. The overlying red sandstones, containing here and there a thin poor coal, are brought into the Dalmellington district by two large faults, which, coming from the north-east, converge and meet not far to the north of Patna.

49. Intrusive sheets of dolerite are more numerous in this district than in the Ayr coal-field. As a general rule, they lie more or less closely along the planes of bedding. Owing to this circumstance, they give to the hilly portions of the district a terraced outline—the softer sandstones above and below them having yielded more extensively to the denuding agents. These dolerites form the hill-tops of Kilmein, Benwhat, Ewehill, Benbeoch, Benbain, etc. A glance at the Map will show that the doleritic masses are faulted and shifted by the dislocations which cross the coal measures. They must therefore have been intruded at a period anterior to the faulting of the district. As these dislocations are partly at least, if not entirely, of earlier date than the Permian rocks, it is inferred that the intrusive masses of dolerite in the coal measures were erupted before the deposition of the Permian series, and that they belong to some late part of the Carboniferous period.

50. The faults in the Dalmellington coal-field are very numerous; those of largest throw have a general north-east and south-west trend. Another set of dislocations—some of which are of considerable extent—runs in a direction nearly at right angles to the former. Of these dislocations, some at least appear to have had their origin after the deposition of the coal measures, and prior to the accumulation of the Permian rocks. With intrusive rocks of the latter period, this district is abundantly studded; and vertical dykes of dolerite, believed to be of tertiary date, also traverse the coal measures. These igneous rocks are described in pars. 60, 63.

Detailed Maps of this Coal-field.—Detailed information regarding minerals, faults, etc. is given in the published Maps of the Geological Survey, on the scale of six inches to a mile—viz. Sheets 40, 46, and 47 of the 6-inch Map of Ayrshire.

e. The Cumnock, Lugar, and Sorn Coal-fields.

51. These coal-fields are simply continuations of the same strata as are developed in the neighbourhood of Dalmellington. At the base of the whole we have the Calciferous Sandstones, presenting much the same character as in the district of the Doon. But whereas, near Dalmellington, the upper or cement-stone division of the series is very

meagerly represented, we find that upper member, in the district under review, attaining a considerable thickness. The underlying sandstones are, as usual, soft red and grey coarse-grained rocks, interbedded here and there with beds of conglomerate and occasional bands of concretionary cornstone. Overlying these comes the cement-stone group, consisting, as in the Doon district, of a set of shales, cement-stones, and grey fine-grained sandstones and flagstones. These cement-stones and shales have yielded many entomostraca and other fossils, and the fine-grained sandstones frequently show worm-tracks, rain-pits, ripple-marks, and sun-cracks. In the neighbourhood of Sorn, the calciferous sandstone series seems to rest unconformably upon the Lower Old Red Sandstone.

52. Next in ascending order comes the Carboniferous Limestone series, which is but poorly developed in this district. The lower limestones are seen at Laigh Holehouse and Blairmulloch, near Sorn, and in Auchinlongford Burn, near Nethershields. The upper limestones occur in the bed of the Ayr at Sorn, near Upper Heilar, and other places. Farther south, in the Cumnock district, the upper limestone is worked at Benston. A coal lying about 7 fathoms below the Pottery Wood limestone was formerly worked at Sorn; near Blairmulloch coal has also been got. At present, the only coal (belonging to the limestone series) which is being raised, is a gas coal at Laigh Brocklar, near Sorn. The strata are much disturbed and dislocated, and the succession of the beds is exceedingly confused, so that it is impossible to give any estimate of the probable thickness of the carboniferous limestone series in this neighbourhood.

53. Between Dalmellington and New Cumnock the upper limestones are seen rising from under the coal measures. In this locality, beds of grit and conglomerate occur a little below the limestones. Coarse conglomerate is likewise associated with the lower limestone series to the south of Dalmellington. These pebbly strata may indicate an original overlap of the Limestone series upon the Old Red Sandstone; a supposition which is further supported by the fact that the thick calciferous sandstone and carboniferous limestone series of Dalmellington die out towards the south-east, until, in the Sanquhar basin, the coal measures rest directly upon Silurian rocks.

54. Above the limestones comes the Coal-measure series. Around New Cumnock the succession of beds agrees with that at Dalmellington. The eastern extension of the black-band ironstone has already been referred to. It may be added that the two uppermost coal seams of Dalmellington—the Sillyhole and Chalmerston—are represented at New Cumnock by the Lanemark and Boig gas coals.

55. In the Lugar district the principal mineral is the black-band ironstone, which appears to occupy somewhat the same position as the black-band at Dalmellington.

The general succession of the beds is as follows:—

	Fms.	ft.	in.
Ell Coal,	0	4	0
Strata,	7	0	0
Main Coal,	0	4	0
Strata,	45	0	0
Claud Coal,	0	2	0
Strata,	7	0	0
Maid Coal,	0	4	0
Strata,	2	0	0
Low Maid,	0	2	7
Strata,	70	0	0
Black-band Ironstone,	0	1	7

56. The coal-bearing strata are here overlaid unconformably by the usual red sandstones; but the unconformity is so gentle as to be readily overlooked in many places. To the west of Sorn, however, the red beds steal over the coal-bearing strata, until they overlap upon the carboniferous limestone series. There is reason to believe that both the limestone series and the overlying coal-beds are thinning out to north-west below the red sandstones. But this question will be more properly discussed in the extended Memoir.

57. In this, as in the other coal-fields, the strata are invaded by intrusive sheets of dolerite. A fine example of the effect produced upon a coal seam by intruded trap, is seen in the railway cutting near Auchinleck, where the Claud coal is converted into a kind of coke, while the igneous rock itself is altered, and takes the form of what is known as 'white trap.' The intrusive sheets of dolerite are not so abundant, however, as in the neighbourhood of Dalmellington. The Lugar district is much broken by faults, some of which are of great extent. Vertical dykes of dolerite also traverse the strata in some places.

Detailed Maps of this Coal-field, on the scale of six inches to a mile, have been prepared by the Geological Survey. They form Sheets 29, 35, 41, and 47 of the 6-inch map of Ayrshire.

Permian.

58. In the centre of the great coal basin of Ayrshire lies a pear-shaped area, occupied by igneous rocks and red sandstones, believed to be of Permian age. Nearly the whole of this area is contained on the present Map. Its structure is exceedingly simple. The rocks of which it is composed are arranged in the form of an oval basin, the long axis being directed from north-west to south-east. At the bottom of the series lies a group of porphyrites, melaphyres, and tuffs—the products of volcanic vents, which were here active during the earlier part of the Permian period. These igneous sheets form the rim of the basin, round which they run as a continuous band. Inside of the rim, and lying above the volcanic masses, is a set of brick-red sandstones, very distinct in colour and structure from any of the red sandstones in the carboniferous formation underneath.

59. The lower or igneous zone consists of a succession of beds of porphyrite and melaphyre, marking different eruptions of volcanic material. It is admirably seen in the course of the River Ayr at Ballochmyle, and again above Stair. Good sections are likewise laid bare in numerous artificial openings along the greater part of its course. The prevailing character of the rocks is that of a dull, reddish brown, amygdaloidal porphyrite, the kernels often full of steatite, and the matrix of the rock usually ferruginous, and more or less decomposed. That this volcanic series really belongs to the Permian system, and not to the underlying coal measures, is shown by its included beds of the characteristic brick-red sandstones, and by the way in which its upper tuffs pass up by frequent intercalations into the overlying Permian sandstones.*

60. But besides these interbedded volcanic masses, this county furnishes other evidence of the number and activity of the Permian volcanos. Outside the Permian basin the coal measures are pierced by numerous more or less circular masses of a coarse unstratified agglomerate. These come up as huge columns or pipes through the coal measures, and appear at the surface usually as small rounded hillocks or

* See *Geol. Mag.* for June 1865.

hills. The coal seams have been worked round and up to them, and have sometimes been found to show the alteration which is usually visible near igneous rocks. Usually these pipes consist of a coarse, irregular, reddish agglomerate, chiefly of different volcanic rocks, but porphyrite or other lava-form rock sometimes occurs. In each case the material closely resembles the Permian igneous masses. There can be little doubt that in these columns or 'necks' we see part of the vents through which volcanic material was ejected in Permian times. Each of these green hills is thus the stump, as it were, of an old Permian volcano. The most numerous 'necks' are those in the Dalmellington coal-field. They are found south-eastwards near New Cumnock, and even in the Sanquhar coal-field. Good examples occur in Raith Hill near Coylton, and in Sorn Hill near Catrine. Other illustrations occur to the north, beyond the limits of the present Map. The details of this interesting subject will be given in the larger Memoir.

61. The overlying red sandstone group is distinguished by the peculiar bright brick-red colour of its strata. It has been cut by the River Ayr into a series of deep and picturesque ravines, along which the characteristics of the strata are well exposed. Similar sections have been excavated by the Lugar Water. The quarries at Mauchline likewise show the quality which some of the strata possess as building stones.

62. The Permian basin, like the coal measures, is traversed by intrusive dolerite. One irregular intrusive mass occurs at Ballochmyle; the other portions are dykes belonging to the north-west or late series.

Igneous Rocks of Miocene (?) Age.

63. In the foregoing paragraphs reference has several times been made to a series of dolerite dykes of later age than any of the other igneous rocks, and running in a north-west and south-east, or somewhat east and west direction. The position of these dykes is indicated on the Map by the narrow strips of dark crimson. At Craighead Hill one of them is seen to cut through altered Lower Silurian rocks; along the shore from Culzean to near the Heads of Ayr, they are found traversing the Old Red Sandstone and its porphyrites; they cut through all parts of the Carboniferous series from base to top, and near the junction of the Lugar and Ayr they are found rising through the Permian sandstones. They vary in thickness from only a foot or two up to 15 or 20 yards. As a rule, they do not run along lines of fault. They preserve their course with singular persistence, irrespective of the changes of dip and strike, or of the varying nature of the rocks. They even cut across large faults without any sensible deviation. It has been inferred that these dykes are connected with the doleritic plateaux of Antrim and the Western Islands, and that they are probably of miocene age.* Probably the best example of them in the district is that (referred to in par. 44) which crosses the Ayr above Auchencruive, whence it runs south-eastward for more than two miles across the coal-field. The coast section to the south of the Doon likewise lays bare some good exposures of these rocks, and of the manner in which they alter the walls of the fissure up which the melted rock has risen.

Faults.

64. Reference has already been made to some of the faults which traverse the districts embraced on the present Map. It will be seen that all the great dislocations run in a north-east and south-west direction,

* See *Proc. Roy. Soc.*, Edin. vol. vi. p. 71; *Brit. Ass. Report*, 1867, Sect. p. 53.

agreeing in this respect with the prevailing trend of the great faults in the central valley of Scotland. One of these defines the boundary of the Lower Silurian and Lower Old Red Sandstone rocks, forming a long straight line between them, and throwing out a vast thickness of strata on the north side. Another runs along the north side of the Girvan valley, and stretches thence north-eastward until it dies away into the coal-field. It depresses all the rocks on its south-east side, bringing down at one place the carboniferous limestone against the lower Llandovery rocks. A third fault is seen on the south side of the same valley, letting down the rocks on its north side. In the coal-fields the prevailing direction is north-west and south-east, or west by north to east by south, and the amount of displacement by these faults is much less than in the great north-east and south-west series.

Drift.

65. Over a large part of the ground which this Map represents, the rocks are concealed under a thick deposit of Drift. Beneath the drift, or on hard rocks from which it has been removed, the surface of the rock is grooved and striated with the characteristic ice-markings of the glacial period. From the trend of these flutings and striæ, as well as from the composition of the drift itself, it appears that the centre of Ayrshire was the meeting-place of the masses of ice which were moving southward from the Highlands, and northward from the uplands of Galloway. Throughout the hilly district of the southern portion of the Map, the ice-striæ point towards the N.W. or N.N.W., but bending round more to the westward, as they recede from the high grounds and approach the Clyde. On the northern side, again, the striæ point towards S.W., as shown on the Lady Isle, and near Prestwick.

66. The drift deposits consist of—

c. Loose earthy débris = moraine stuff.
b. Sands and gravels, and stratified clays.
a. Upper and lower boulder clay.

The boulder clay varies in colour and composition, according to the districts in which it occurs. Among the Silurian rocks it is of a pale grey; on Old Red Sandstone it is red; on the coal-fields it is usually dark grey, blue, or brown. The stones it contains are for the most part well striated and local in character. As we advance northward, however, and come within what was probably the area of the ice that drained from the Highlands, we meet with occasional fragments of gneiss or mica-schist, which must have come from the Highlands. These are found in the valley of the Lugar, and westward to the northern slopes of the Brown Carrick range. To the west of Stair, gravel and a bed of peat are found below the boulder clay. Stratified sands, gravels, and clays occur in the boulder clay itself, particularly along the chief valley lines. It has not been found possible, however, to map out these intercalations, or to subdivide the boulder clay into well-defined zones. No fossils have yet been found in the boulder clay in any part of these districts.

67. There are many indications that the drift has been laid down with a very irregular surface. Some of the most striking are to be found in the numerous hollows, either now or formerly filled with water. Such hollows must be due to original irregularities of the drift deposits, as no surface action could have produced them. In the district between Ayr and the Girvan valley, they may be counted in dozens. Although comparatively few are still covered with sheets of water, they have all

evidently been so at no very distant date; and in some of them may be seen the process of silting up, by which the lake is gradually converted into the meadow.

68. The overlying sand and gravel group is only scantily developed in Ayrshire. It forms some well-marked ridges or kames, about a mile and a half to the north-west of Ochiltree. It may be seen also in a line of kames which stretches up the valley of the Nith by Sanquhar and New Cumnock, and extends for some way in the line of the railway. Between Old and New Cumnock some of these sand and gravel mounds enclose a few small lochs. Another line of kames, about 1000 feet above the sea, runs along the hollow between Benbrack and Clawfin, to the east of Dalmellington. In the neighbourhood of Maybole also, there is a series of gravel and sand ridges, rising in places into well-marked kames. Similar mounds occur on the south side of New Dailly. Near the sea there is sometimes a considerable covering of sandy and gravelly deposits not ridged up into definite kames.

69. Fine clays without stones occur in many parts of the area embraced in this Map, usually in hollows, and therefore referable possibly to the accumulation of silt washed by rains and rills off the slopes of boulder clay. Some of these clays, however, may belong to the Glacial series, though the absence of fossils and the want of continuous sections make their true relations somewhat obscure. In only one instance have organic remains been detected in these deposits. This was in a bed of fine clay, cut open by the Pow Burn, about a mile to the east of Monkton. Here shells of Arctic species occur; among them *astarte compressa* and *natica clausa*.

70. Erratic blocks are abundant throughout the southern half of Ayrshire. Like the striæ on the rocks, and the stones in the boulder clay, they point to the former existence of large masses of ice on the southern hills. They consist in great part of grey granite, derived from the granite hills, which rise among the Silurian rocks from near New Cumnock, southwestwards by Cairnsmore of Carsphairn and Loch Doon, to the sources of the Girvan and Stinchar. These blocks are found at least as far north as the hills overlooking the lower reaches of the River Doon. They are sometimes of large size, one of the largest—the Baron's Stone of Killochan—measuring about 480 cubic feet. They lie by thousands in the valley of the Girvan, and over the sides and summits of the adjoining hills. Farther east they are found even as high as 1865 feet above the sea, on the top of Enoch Hill, which is separated from the granitic mass of Cairnsmore by four miles of intervening hill and valley.

Raised Beaches.

71. Along the coast-line, at varying distances from the present sea margin, there are indications of former sea-levels in the form of more or less perfectly preserved terraces. To the north-west of Kirkoswald, below the farm of Jameston, there is one of those terraces at a height of between 60 and 70 feet above mean tide-mark. Traces of another at a somewhat lower level occur between Monkton and the old church of Crosbie. To the east of the Ayr racecourse there is the remnant of a third terrace, at a height of between 45 and 50 feet above half-tide, corresponding probably with the well-marked 40-feet beach of the west of Scotland. The same terrace is seen in fragments at intervals along the coast-line to the south. But the most persistent and best marked of the terraces is the lowest and most recent, occurring at an average height of about 25 feet. It forms along the present coast-line a strip of flat land

stretching northwards for many miles from the mouth of the Doon. On this terrace all the coast towns of the district are built. It consists of layers of sand and gravel identical in character with those forming on the present beach. Throughout a great part of its course, however, its surface has been much heightened and made uneven by inroads of blown sand driven landwards from the beach. Cultivation has done much to smooth the inequalities thus produced; but the influence of the drifted sand in altering the aspect of the raised beach may still be well seen in progress at Prestwick.

Blown Sand.

72. From New Prestwick northwards for many miles, the coast-line is marked with ridges of sand hills driven up by the wind from the present beach. Where vegetation has been able to get a firm footing, the shape of the mounds may remain for a long time unchanged; but where the sand lies exposed to the wind, the mounds undergo modifications during every gale. As mentioned in the foregoing paragraph, the inequalities of surface which mark the lowest of the raised beaches are in great measures due to the former drifting of blown sand, although the ground has now been cultivated for many centuries. The town of Ayr was formerly much exposed to inroads of sand.

Alluvium, Peat, Soils.

73. Under the term *alluvium* are comprised all the deposits of clay, sand, silt, loam, or gravel deposited by streams or by rain. The Map shows the disposition of this alluvium along the water-courses, and the manner in which the streams wind across it from side to side. In many cases the alluvium of a river valley consists of several terraces rising over each other, that of the present stream being the lowest. Good examples of such terraces are found along the course of the Ayr between Stair and its mouth. In addition to the stream alluvia, there are many small isolated patches marking the sites of ancient bogs or lakes. These are particularly numerous between Ayr and the valley of the Girvan (see par. 67). They are now for the most part occupied by flat meadows or cultivated fields; some are still marshy; a few yet show a diminished representative of the lake which once filled the hollow,—while here and there, where the slopes of the hollow have been steeper and its bottom deeper, or where the inflow of sediment has been small, the lake still continues to cover most of its original area. Some of the lakes have been drained artificially and converted into arable land. Others, as Tarbolton Loch, are sometimes meadows and sometimes sheets of water, according to the wetness or dryness of the season.

74. Much of the south of Ayrshire was formerly covered with peat and heather, which is now cultivated. But there still remain many peat-mosses, some of them of considerable size. They lie both on the low grounds and among the hills, sometimes in small hollows, sometimes in broad, open valleys. One of the most considerable is Aird's Moss, between the Lugar Water and the River Ayr. Other large areas of peat cover the hilly grounds to the east and south-east of Dalmellington. Many of the small alluvial hollows referred to in the preceding paragraph contain deposits of peat. A great deal of the peat now no longer continues to grow. On hilly grounds it often cracks up and is blown away as dust by the wind, or is washed off by rain, so as to present a brown verdureless surface, roughened with stumps of heather, or projecting trunks and roots

of ancient trees. On low lands or in hollows, the dead peat gets covered with heath or with coarse grass.

75. The distribution of soils in Ayrshire follows approximately that of the geological formations beneath the surface. On the hilly tracts the covering of soil is usually thin and stony, but light and dry; and when its heather is burnt off, it affords good pasturage. Where the boulder clay spreads over the valleys and lowlands, it usually gives rise to a stiff, retentive soil. This is the character of much of the eastern and north-eastern districts. The sandy and gravelly parts of the Drift series are covered with a good free soil; but the richest soils are, as a rule, those which lie along the alluvial plains, as in the lower parts of the valleys of the Ayr, Doon, and Girvan.

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EXPLANATION OF SHEET 15.

DUMFRIESSHIRE (North-West Part); LANARKSHIRE (South Part); AYRSHIRE (South-East Part).

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PREFACE.

The Map of which the present pamphlet is an Explanation has been surveyed under my direction, and with the approval of the Director-General, Sir Roderick Murchison. All the ground lying to the north-west of the great fault bounding the Silurian uplands has been mapped by Mr. B. N. Peach, as well as a strip of ground on the south-east side of that fault stretching from the Clyde by Crawfordjohn, Upper Whitecleugh, Spango Water, Kirkland Hill, and from Upper Cairn along the southern limits of Ayrshire to the south-west corner of the map, including the Sanquhar coalfield. South of that strip the Silurian tracts have been mapped by Mr. R. L. Jack as far south as a line drawn from the head of the Euchan Water along the watershed between that stream and the Scar Water to the Nith at Dalpedder Hill, thence along the crest of the Lowther range to Leadburn Rig, and as far east as a line striking from the last-named locality north-westward by Glendowran Burn to the Duneaton Water. East of Mr. Jack's area the survey was carried on by Mr. Harriman Skae into the adjoining sheet (16), and southwards from the Lowther range by Durisdeer through the Silurian hills into the next map on that side (sheet 9). South of Mr. Jack's ground, the remainder of the Silurian tract was surveyed by Mr. John Horne from the head of the Afton Water eastwards to the Enterkine Burn and the Nith. The Permian and Carboniferous basin of the Carron Water and Thornhill was surveyed by myself.

ERRATUM.

By a typographical error, the numbers referred to in the second paragraph of the Preface have been deranged. The reader is requested to insert the subjoined corrected paragraph in its place.

Of the following Explanation, Mr. Peach has supplied paragraphs 18, 24, 38–40, 45–53, 56–76, 88–90, 93–98, 106, 107, 109 and 110; Mr. Jack, paragraphs 7, 13, 19, 20, 23, 25, 28–31, 36, 102, 108, and 111; Mr. Skae, paragraphs 14–17, 21, 22, 26, 27, and 37; Mr. Horne, the account of the glaciers given in paragraphs 100 and 101. Paragraphs 1–6, 8–12, 33–35, 41–44, 54, 55, 77–87, 91, 92, 99, 103, 105, and 112, have been written by myself; and I have, as usual, arranged and edited the whole.

EXPLANATION OF SHEET 15.

I. DISTRICTS EMBRACED IN THIS MAP.

1. In the present Map are represented 432 square miles of the high-lying ground between the sources of the Nith and the Clyde, stretching from Aird's Moss eastwards by Cairn Table and the Douglas coalfield to beyond Abington, and southwards by New Cumnock, Sanquhar, and the Leadhills, to Cairnsmore, Drumlanrig, and the hills about Queensberry. The Map thus includes the coalfields of Kennox, Muirkirk, Lugar, New Cumnock, and Sanquhar, as well as the mineral tracts of Wanlockhead and Leadhills. Most of its area lies within the broad tract of Silurian uplands of the southern counties of Scotland, while its north-western portions come into the Carboniferous and Old Red Sandstone tracts of the great Midland Valley. About three-fifths of the Map lie, half in Dumfriesshire, half in Lanarkshire; the remainder lies in Ayrshire, except a small fraction at the south-west corner, which comes into Kirkcudbright.

II. FORM OF THE GROUND.

2. Occupying, as it does, part of the watershed between the Solway and the Firth of Clyde, the area embraced in this Map is almost wholly hilly ground. It may be divided into two regions, separated from each other by the long straight N.E.-S.W. fault, which cuts off the Silurian uplands from the uneven ground to the north-west.

3. *The Silurian Area.*—Of these two regions, that which lies to the south-east, and forms the greater part of the Map, belongs to the great Silurian table-land of the south of Scotland, and exhibits the well-known characteristic surface-features of that tract of country. Although everywhere hilly, it contains no definite ranges or systems of hills. It must rather be regarded as an undulating area of high ground, cut into winding valleys, between which the ground rises into irregular ridges. Its surface is almost everywhere smooth, flowing, and covered with turf or heath; and only here and there, where the valleys narrow, or where some harder bed of rock protrudes from a hill side, do we meet with cliffs and rocky scars. It is traversed by two main valleys, that of the Nith and that of the Clyde, the waters of which flow in opposite directions across the Silurian uplands. Both the Nith and the Clyde flow obliquely across the strike of the Silurian strata, although, on the whole, they may be regarded as occupying transverse valleys. Their tributaries ought to be looked upon as lying in longitudinal valleys, but they do so only in a very general sense, since they wind and curve across the general trend of the rocks with as much independence as their principals. Hence the

intervening ridges of the old table-land are not regular and parallel hill-ranges, but irregular masses which have been left standing, during the general erosion of the valleys, between them. It is the excavation of the valleys which has determined the form of the hills. Nevertheless, the influence of the geological structure of the rocks, in guiding the gradual sculpture of the hills formed out of them, can still be traced, in the general trend of the ridges in a north-easterly and south-westerly direction, that is, along the strike of the rocks. The long bank of the Lowthers, for example, runs for five or six miles in the same line as the strike of the Silurian strata of which it is composed. This is the best and indeed almost the only noticeable example of the coincidence of the line of ridge with the line of strike of the rocks. But even where the coincidence is more faintly marked, we see everywhere a kind of striving after a north-easterly trend, as if geological structure could only exercise a pervading but not very potent influence upon the process of denudation. The Silurian strata of this area are highly inclined and folded, but the anticlinal arches do not form ridges, nor the synclinal troughs hills; on the contrary, the Lowther ridge runs along a synclinal fold.

4. The form of the surface in the Silurian area is partly of very ancient date. There can be no doubt that the Silurian rocks were curved and then denuded before the time of the Lower Old Red Sandstone, and that they were here overspread by some 10,000 or 12,000 feet of that formation. What was the form of the Silurian ground at that ancient date we have now no means of ascertaining, for that great depth of overlying Old Red Sandstone has been since so entirely removed, that no trace of any portion of it now remains. We know, however, that this vast denudation took place previous to the time of the Carboniferous Limestone, for that formation occurs in different parts of the Map, resting directly on the Silurian rocks, without the intervention of any Old Red Sandstone whatever. The Silurian region, bared of its Old Red Sandstone, had been cut out into valleys, in which the Carboniferous Limestone was laid down; and these valleys are valleys still, since the Carboniferous and Permian strata, under which they were eventually buried, have since been in great measure removed.

5. Thus only after a vastly prolonged denudation has the Silurian area been brought into its present form of surface. The largest and highest fragments which remain of the original table-land out of which the existing valleys have been carved, form the group of the Wanlockhead, Leadhills, and Lowther Hills, between the Nith and Clyde, and the high grounds about the sources of the Afton, Euchan, Snar, and Ken waters. In the Lowthers the highest point is 2403 feet above the sea, and a space of about two and a half square miles exceeds an elevation of 2000 feet; while on the south-west side of the Nith the area above 2000 feet amounts to rather more than a square mile, its highest point being the Black Craig of Afton, which has an elevation of 2298 feet. The only cliff of any size in the district is Glenwhorgan Craig, in the valley of the Scar water, which has a height of upwards of 400 feet. It is on the north-east side of the Nith, however, that the valleys are deepest and narrowest. This is particularly to be observed on the south side of the Lowther Hills, in such valleys as that of the Enterkin, or of Dalveen, and in their tributaries. Yet though the slopes are steep, they are almost always grassy or heathy; and where rock does roughen them, it is for the most part only in detached little crags and hummocks. The steep green declivities of the Pass of Dalveen, and of the minor valleys which enter into it, form a singular feature in the scenery of this region.

6. In this, as in other parts of the Silurian uplands of the south of Scotland, there occur examples of dry ravines or hollows running along

hill-sides, but truncated at either end, and not now occupied by running water. One of these curious hollows occurs at Dunmoss, near Elvanfoot; and a more remarkable instance occurs on the south-east end of Crucreach Hill. Such fragments of older systems of drainage help us to realize the long series of denudations which these uplands have undergone.

7. There is only one natural sheet of water in the Silurian region—Polvaird Loch—which measures 700 feet long by 200 feet broad, and lies at a height of 1760 feet above the sea, on a col of the great ridge between the Scar and Euchan waters. It is surrounded and retained by peat, and appears to have originated in the gradual decay and removal of the central part of the peat moss of this col. During dry weather the peat cracks and crumbles away into dust, which is blown off by the wind; and hence a hollow might have been worn in the middle of the moss capable of holding water, and of being increased in size by the same process.

8. *Tract to the N. W. of the Great Fault.*—The Silurian area is flanked on the north-west by an irregular series of widely-parallel ridges and valleys, which, running from S.W. to N.E., correspond in direction with the general strike of the Old Red Sandstone, conglomerate, and igneous rocks of which they are chiefly composed. In this district, as in that already described, there is a twofold valley-system, one series transverse to the strike of the rocks and trend of the ridges, the other more or less parallel with the strike. The former are most marked, and descend for the most part to the north-west, towards the valley of the Ayr, which is here itself a longitudinal valley. One important stream, the Duneaton water, however, flows in the opposite direction, and actually crosses into the Silurian region, where it flows along a longitudinal valley, until its waters are caught and carried back again out of the Silurian tract by the transverse valley of the Clyde.

9. The highest part of this district is Cairn Table (1944 feet), which forms a central dome of high ground, whence the Garpel, Duneaton, and Parishholm waters diverge. This dome, however, is merely the highest portion of one of the long N.E. and S.W. parallel ridges which have been referred to as characteristic of this part of the country embraced in the present Map. Another of these ridges, formed mainly of a great conglomerate band, runs from the Duneaton water south-westwards until it ends in the bold eminence of Corsincone, which, rising to a height of 1547 feet, forms a conspicuous landmark in Nithsdale.

10. *Form of the Ground little affected by Faults.*—In the present Map the comparatively trifling influence exerted upon the form of the surface by even large faults is well shown. The great boundary fault along the north-western margin of the Silurian region, must be a dislocation of at least 10,000 or 12,000 feet, as will be shown on a subsequent page. Yet this great fracture has not given rise to any long depression, valley, or gorge. Sometimes it runs along a valley, sometimes over a hill, sometimes along a ridge. But what is still more noticeable, it is crossed by a long series of transverse valleys, and in more than one instance it is traversed twice by the same stream. The large valleys of the Clyde and Nith have been excavated across this dislocation, as well as the minor depressions, in which flow the Afton, Duneaton, Black Burn, and Mill Burn, besides still smaller streams. The Nith rises in the Silurian region, and after flowing across the large fault (see Sheet No. 14 of the Geological Survey Map of Scotland) into the Carboniferous district, it turns round at New Cumnock, and again crossing the fault, flows completely across the Silurian uplands into the Solway. The Duneaton water and its tributaries from the north-west in like manner cross the great fault, and again repass it when their waters are carried off to the north in the Clyde.

III. FORMATIONS AND GROUPS OF ROCK ENTERING INTO THE GEOLOGICAL STRUCTURE OF THE REGION EMBRACED IN THE MAP.

Aqueous.

		Sign on Map.
Recent and **Post-Tertiary.**	Alluvium, Peat.	
Drift Series.	Moraine mounds. Sands and Gravels. Erratic blocks. Boulder-clays.	
Permian.	Red Sandstones and Volcanic rocks,	e
Carboniferous.	Coal-measures,	d^5
	Millstone grit,	d^4
	Carboniferous Limestone series,	d^2
	Calciferous Sandstone series,	d1 and d^1
Lower Old Red Sandstone.	Red Sandstones, Conglomerates, and associated Volcanic rocks,	c^1
Upper Silurian.	Ludlow and Wenlock rocks,	b^5
Lower Silurian.	Caradoc beds,	b^3
	Llandeilo beds,	b^2

Metamorphic.

Altered Lower Silurian strata,	β^2
Dioritic rocks, etc., in Lower Silurian series,	Di?

Igneous.

1. *Interbedded or Contemporaneous.*

In **Permian.**	Porphyrite, Tuffs, etc.,	Fe
„ **Carboniferous.**	Basalt-rocks and tuffs,	Fd
„ **Lower Old Red Sandstone.**	Porphyrites, Melaphyres, and Tuffs,	Fc

2. *Intrusive or Subsequent.*

Of **Miocene** (?) age.	Dolerite dykes,	Gn
„ **Permian** age.	Necks of Agglomerate,	Ne
„ **Post-Carboniferous** age.	Sheets of Basalt-rocks,	Gn
„ **Lower Old Red Sandstone** age.	Felstones,	F
„ **Post-Llandeilo** age.	Felstones in Lower Silurian series,	F
——	Diorite dykes,	Di
——	Granite,	G

IV. GEOLOGICAL STRUCTURE OF THE DISTRICTS CONTAINED IN THE MAP.

11. In the following descriptions each geological formation which occurs in the Map is described in stratigraphical order, beginning with the oldest. Where the area covered by a formation is scattered, or is more conveniently treated under topographical subdivisions, it is divided and described in separate districts.

Lower Silurian.

12. By the valley of the River Nith the Lower Silurian area of this Map is divided into two parts, which present sufficient topographical and geological differences to merit separate description. The district to the north-east of the Nith will be termed the Leadhills District, and described first, as containing the clearest section of the order of succession among the rocks of this part of the country. The area to the south-east of the Nith will, for convenience of reference, be called in the following pages the Sanquhar District.

a. Leadhills District.

1. Llandeilo Beds.

13. The geological structure of this district is best seen by taking a section from near Crawfordjohn across the Snar water, Leadhills, and the Green Lowther, to the valley of the Potrail water. In this section the Lower Silurian rocks traversed may be regarded as forming one great synclinal trough, since the lowest strata, which are seen to the north-west along the great boundary fault, rise again to the surface on the south-east side along the valley of the Potrail water. In reality, however, this synclinal trough is folded into several minor synclinal and anticlinal curves, so that the same series of beds is repeated more than once along the line of section. Two divisions of the Lower Silurian system are here represented—the Llandeilo and the Caradoc beds. The Llandeilo series consists of seven well-marked local groups of strata, which, for the sake of clearness, will be described separately in ascending order. They consist of the following divisions :—

H. Caradoc or Bala Beds.

Llandeilo Beds.

G. Black Shale Group.—Grey shales, with bands of fine-grained blue greywacke and flinty mudstones, the most characteristic feature being the interpolation of numerous bands of dark anthracitic shales with graptolites—Estimated thickness . . . 3400 ft.

F. Lowther Group.—Fine grey shales, and finely laminated felspathic greywackes, with occasional grit beds—Estimated thickness . 5000 ft.

E. Haggis Rock Group,—consisting of coarse and fine grits and greywackes, with associated bands of red and green flinty mudstone, conglomerate, and occasionally breccia. The most marked feature of the group is the occurence of a persistent band of conglomerate containing pebbles of quartz rock, Lydian stone, and jasper, locally known as the 'Haggis Rock'—Estimated thickness . 1800 ft.

D. Dalveen Group.—A series of fine blue and grey greywackes and shales, having no marked characteristic to distinguish them from the other members of the Llandeilo series—Estimated thickness 2900 ft.

C. Daer Group.—A series of hard blue and purplish greywackes and grey shales—Thickness not ascertained.

B. Hartfell Shale Group.—Black and grey shales with graptolites—Thickness not ascertained.

A. Queensberry Grit Group.—Grey and purple gritty greywacke, with occasional bands of pebbly grit—Thickness not ascertained.

14. **A. Queensberry Grit Group.**—This group of strata only comes into the extreme south-east corner of the Map. It forms Queensberry Hill (Sheet 16), and stretches north-eastward by the north of Moffat, forming a band of rough craggy hills. This mass of rocks, as well as group B, fall to be described more appropriately in the Explanation to accompany Sheet 16.

15. **B. Hartfell Shale Group.**—One of the characteristic black shales of this group comes into the south-east corner of the Map, and is seen on the crags at the head of the Capel burn. It contains a few graptolites, but these will be described in the Explanation to Sheet 16.

16. **C. Daer Group.**—This mass of strata occupies in the south-east corner of the Map the basin drained by the Daer water and its tributaries north-westwards to a line drawn from Durisdeer by Well Hill, Coom Rig to Tomont Hill. It consists of hard blue and purplish gritty greywacke, accompanied by, and interbedded with, grey shales and shaly greywacke. The greywacke generally occurs in bands of a foot or so in thickness, separated by hard thin shaly courses. Sometimes, however, it is met with in great thick masses which present no trace of bedding. It often contains much diffused iron, which oxidizes, and causes it to assume a dull red colour in the midst of beds of the usual grey or purplish tints. This is more observable in the neighbourhood of dykes, and where the rock is much broken up by joints. In some places it has a coarsely schistose structure, breaking under the hammer with a shivery fracture. The shales frequently become very sandy and micaceous, decomposing with an olive-green colour to a considerable depth. The prevailing strike is a north-easterly one, the beds dipping at high angles to the north-west, or in many cases being vertical. Although it is not easy to detect in this area actual foldings of the beds, it is highly probable that many such do occur, and that the same strata are repeated again and again, though, owing to the reversal of the dips, the whole seem to slope towards the north-west. Under these circumstances, no reliable estimate can be formed of the thickness of this group in the present district.

17. **D. Dalveen Group.**—North of the line which has been indicated as limiting the Daer group, lies a considerable thickness of hard grey flaggy shales, with bands of dark gritty greywacke. Their strike is the same as that of the last group, and, although nearly vertical, they show on the whole an inclination towards the north-west. They are well exposed in the Dalveen Pass. Their bedding is sometimes much jointed, contorted, slickensided, and veined with quartz. Other evidence of the extent to which these strata have suffered metamorphism is shown by the frequent corrugated texture of their laminæ, and also by the occasional appearance of a distinct set of cleavage planes, which, on the slope of the Laght Hill, are inclined at a high angle in a direction opposite to that of the planes of stratification. This group of beds in the Dinabid Linn passes under a bed of coarse pebbly conglomerate, which is regarded as the equivalent of the 'Haggis Rock' to be immediately described.

18. On the north-west side of the Silurian area, abutting against the great boundary fault, there comes a group of beds which are probably the uppermost part of the Dalveen group. They consist of a series of dark blue flaggy shales, with bands of dark greywacke, very much jointed and shattered, in some cases so much so, that, as the fragments have been re-cemented, a brecciform rock has been produced, which has in turn been cut up by a new series of joints. The rocks in this area are highly inclined, almost vertical, but dip steadily away from the large fault, and plunge under the Haggis Rock series. The estimated thickness of the Dalveen group is 2900 feet.

19. **E. Haggis Rock Group.**—This series of beds is seen along the north-west margin of the Silurian area, from the Clyde at Mote, by Crawfordjohn, Fingland, and Kirkland Hill, to the edge of the Sanquhar coalfield, on the other side of which it is again seen striking across the Afton into Sheet 14. Throughout this tract its general dip is south-easterly, at an average angle of about 65°. It consists of thin bedded shaly greywackes, hard red mudstones, and fine conglomerates. The bottom bed in the neighbourhood of Mountherrick is taken to be a band of breccia made up of fragments of shale. This is succeeded by flinty red mudstones, in which occurs the bed of conglomerate, locally known as 'Haggis Rock,' from which this group has been named. The pebbles of this conglomerate are

chiefly of quartz, jasper, and Lydian stone, varying in size from that of a pea to that of a large walnut. From its hardness and its characteristic texture, this band of conglomerate forms a marked feature along the north-western margin of the Silurian area; and its fragments, whether lying loose on the surface, or imbedded in the drifts, can be recognised all over the lower grounds for a number of miles to the north and north-west. The Haggis Rock is succeeded by a series of fine hard greywackes, with occasional bands of grit and shale, the uppermost bed being one of fine conglomerate. The thickness of the whole group between this upper conglomerate and the bottom breccia is estimated in the Mountherrick district to be about 1800 feet.

20. By a great synclinal fold of the Llandeilo rocks, the Haggis Rock group, after plunging underneath a vast thickness of overlying strata, rises again to the surface along the north-west flank of the Lowther ridge. It is there exposed underlying the Lowther beds in the Glen Franka burn, where it exhibits a conglomerate containing small pebbles of quartz and angular fragments of hardened shale, which may be the equivalent of the uppermost conglomerate bed of the Haggis Rock group above referred to. Where seen, these beds have a north-west dip; but they probably curve over immediately in the opposite direction, thus forming the crest of an anticlinal axis, since they are succeeded a little to the south-east by the great overlying mass of the Lowther beds.

21. What appear to be the same strata are found on the north-western slope of Lousie Wood Law, whence they may be followed as a continuous band of considerable thickness, which, forming often a marked feature along the hill-sides, is prolonged beyond the other side of the Clyde across the Cakelaw and Glespin Burn. As it is traced to the north-east, this conglomeratic band becomes much finer in grain, until it passes into a gritty greywacke. Where its conglomeratic texture is best seen, it is made up of well-rounded pebbles of quartz, grit, greywacke, and Lydian stone, with angular fragments of hardened shale in a matrix of greenish-grey quartzose grit. In some places, where the matrix is scanty, or even almost wholly absent, the stones may be observed broken and squeezed into one another. As exposed in the Glespin Burn, the grey micaceous shales, associated with the conglomerate, are either vertical, or dip at a high angle to the south-east.

22. The south-easterly dip with which the Haggis Rock group plunges under the Lowther Hills is succeeded by a dip to north-west, so that the ridge of the Lowthers lies in a synclinal trough, and the Haggis Rock group is brought up again along its south-eastern flank. In the Dinabid Linn, which descends into Dalveen Pass, a bed of coarse pebbly conglomerate is found associated with courses of greywacke and dark crumbling shale. In composition and texture, this conglomerate agrees with the corresponding bed to the north-west. It has here a north-easterly dip, which, however, may be merely local, indicative perhaps of another minor fold; for a little to the north-east, in the two streams flowing east from the Lowther Hill, two bands of similar conglomerate are found with a north-westerly dip, passing under the ridge of the Lowthers. The conglomerate has not been recognised in any of the other streams descending from the east side of that ridge; but still further to the north-east, on the side of the road to the south-east of Watchman Hill, and again in the small stream which flows south from Lady Cairn to join the Clyde, alternations of coarse brecciated conglomerate and pebbly grit occur.

23. **F. Lowther Group.**—Overlying the group of which the Haggis Rock is the prominent feature, comes a great thickness of finely-laminated and flaggy blue felspathic greywackes and thin-bedded shales,

with occasional beds of grit. This group of strata is well seen in all the streams descending from the crest of the Lowther ridge, which is formed of them, and from which their local name has been taken. As already mentioned, they lie here in a synclinal trough, the centre of which corresponds in a general sense with the trend of the ridge of the Lowthers. The top of the group is not reached in this synclinal fold. To the north-west, however, the whole thickness of the group is met with along the ridge which, between Leadhills and Crawford, separates the valleys of the Elvan and Glengonnar waters. The best section of these strata, in the present district, occurs in the cutting of the Caledonian Railway at Crawford. It is in this group of strata, as developed along the Leadhills line of outcrop, that the mineral veins of Leadhills and Wanlockhead chiefly occur.*

24. By the great synclinal fold in which the Caradoc trough lies, the Lowther beds are again brought up with a south-easterly dip, ranging from the margin of the Sanquhar coal-field north-eastwards by the valley of the Duncaton water to the Clyde. They are much altered, as will afterwards be described, round the granite of the Spango water, but in the streams descending into the Duneaton water their characteristic features are well displayed. The estimated thickness of the strata which form this group is 5000 feet.

25. **G. Black Shale Group.**—The main mass of the beds entering into the composition of this group does not essentially differ in lithological character from the group last described. It is, however, distinguishable from it by the occurrence of bands of red and green flinty mudstone, and of black anthracitic, pyritous, occasionally gnarled shales, containing graptolites. This group is curved into a great synclinal trough, which, flanked on either side by the underlying Lowther beds, has its centre occupied by the Caradoc group (**H**), of Duntercleuch and Glendowran. The black shale bands are numerous, and the group containing them may be traced by their means along the southern side of the basin in a zone of over a mile in breadth, from Cogshead, by the smelting mills at Wanlockhead and Leadhills, to Laggen Gill near Abington. Good sections of the graptolitic shales may be seen in Cog Burn, Wanlock Water near Raecleuch Hill, Sowen Burn behind the Wanlockhead Smelting-mill, and Glengonnar Burn (east of Black Hill). The lowest beds of this series may be seen resting on the Lowther beds in the burn south of the Wool Law, Leadhills, while the uppermost beds dip under the Caradoc group at a high angle in Back Burn, Wanlockhead, and Glenkip Burn, Leadhills. In Snar Water, south of Hunt Law, and at the head of the Glenkip Burn, beds of this group may be observed much crumpled and folded. The estimated thickness of the Black Shale group is 3400 feet.

26. In continuation of the zone from Cogshead to Laggen Gill, a band of black pyritous shales is exposed on the eastern base of Craig Dod, near Abington, and also in the Glencaple Burn. The same shales are seen in the railway cutting under the bridge opposite to Kirkton, and, skirting the southern slopes of Southwood Rig and Tewsgill Hill, are prolonged by the head of Ringwood Gill into the adjoining Map (Sheet 16). Another bed runs from Glengonnar Mill to the north-east, by the head of the Raggen Gill and Coldchapel Burn, to Rein Gill near Birnock. The shales are dark grey or black; usually soft, crumbly, and glossy. In most instances they are profusely veined with white quartz, jointed and slickensided. Sometimes they are interstratified with dark grey siliceous courses. Although retaining well-marked bedding, they have undergone much contortion and metamorphism.

* The general trend of the mineral veins is shown upon the Map, and a description of their general character is given in par. 112.

27. The flinty mudstones, already referred to as characteristic of this group, here consist of indurated green, red, or chocolate-coloured mudstones or shales, with thin courses of dark flinty slate or Lydian stone. The latter are shattery, and much veined with quartz. These rocks extend, with an average breadth of one mile, from Craig Dod to the north-east, by Southwood Rig, Tewsgill Hill, Rome Hill, and thence into the adjoining sheet. More metamorphosed portions, to be presently described, occur sporadically on both sides of the Clyde, between Abington and Crawford. On Harkwood Rig, a vertical bed of coarse serpentinous conglomerate appears, and seems to form a lenticular patch in the red indurated shales. It consists of well-rounded stones of different flinty altered rocks, in a dirty green, sandy decomposed matrix, veined with carbonate of lime. In some places it is a mere uncompacted assemblage of stones, without any visible trace of stratification.

28. On the north-west side of the Caradoc trough (**H**), the black shale series reappears, where its characteristic beds may be traced dipping persistently to the south-east, from the edge of the Sanquhar coalfields, near Towerhill, north-eastward to Whiteside Hill, near the head of the Crawick water. For about three miles further on in the line of strike, the black shales of this group are concealed partly by the grassy surface of the ridge of the Windy Dod, and partly by the Permian outlier of Glendowran Burn. On the north-east side of this outlier, however, a black shale containing graptolites occurs between Cleuch and Glentewing, whence it may be inferred that, although not seen, the black shales are nevertheless continuous. The Caradoc group, which occupies the centre of a great synclinal fold of the Black Shale series, 'noses out'* to the south-west about Wedder Dod, from which point, south-westward, the trough is formed of the Black Shale group.

29. *Fossils of this Group.*†—The following list proves that the Black Shale group belongs to the upper portion of the Llandeilo series:—

Hydrozoa Graptolithus Hisingeri.—*Carr.*
—— Nilssoni.—*Barr.*
—— tenuis.—*Portl.*
—— *sp. nov.* (?attenuatus).—*Hopk.*
—— Sagittarius.—*Linn.*
Diplograpsus angustifolius.—*Hall.*
—— mucronatus.—*Hall.*
—— pristis.—*His.*
—— quadri-mucronatus.—*Hall.*
—— tamariscus.—*Nich.*
—— tricornis.—*Carr.*
—— Whitfieldi.—*Hall.*
sp. nov. (? Etheridgei).—*Hopk.*
Didymograpsus elegans.—*Carr.*
Nemagrapsus linearis ?
Dicellograpsus elegans.—*Carr, sp.*
—— Forchhammeri.—*Gein, sp.*

Hydrozoa Dicellograpsus Moffatensis. *Carr, sp.*
Dicranograptus formosus.—*Hopk.*
—— Nicholsoni.—*Hopk.*
—— ramosus.—*Hall.*
—— sextans.—*Hall.*
—— Clingani.—*Carr.*
Climacograptus bicornis.—*Hall.*
—— minutus.—*Carr.*
—— teretiusculus.—*His.*
Corynoides calicularis.—*Nich.*

Brachiopoda Discina *sp.*
Siphonotreta micula.—*M'Coy.*

2. Caradoc Beds.

30. **H.** *Caradoc Group of Duntercleuch and Glendowran.*—The great synclinal curve of Llandeilo rocks in the Leadhills district is occupied by a central group of beds, which, from the fossils found in them, have been ascertained to belong to the Caradoc or Bala series. A reference to the Map will show that this Caradoc trough extends from the neighbourhood of Wedder Dod, in a north-easterly direction, at least as far as

* This phrase, which has been used for some time by the Irish Geological Survey, implies that strata folded into a synclinal trough approach the surface at either end of the trough, and finally crop out in the line of axis, their place being taken by lower strata.

† These and the other fossil lists have been determined by Mr. Etheridge.

the hills on the right bank of the Clyde below Abington. Beyond that locality, it has not yet been satisfactorily traced. The strata found in this well-marked trough consist of greywacke, passing, on the one hand, into crumbling sandstone, and, on the other hand, into pebbly grits, with partings of shale resembling that of the Lowther series, and with beds of conglomerate, which are chiefly found at the base of the group. In mapping the district, the basement beds of the Caradoc series were taken to be two bands of conglomerate, in which the pebbles, chiefly of quartz, vary in size, from that of a small pea to that of a hen's egg. Not far from the bottom of the trough, in a streamlet coming southward into Glendowran Burn, a little concretionary limestone is seen,—the only example of limestone met with in the Lower Silurian rocks of this Map. No fossils could be found in it; but the conglomerates, and a few of the gritty or pebbly beds higher up, were found, in the course of the Survey, to be abundantly fossiliferous,—the fossils indicating a Caradoc or Bala horizon. The total thickness of strata in this group amounts to about 1700 feet; but the top of the series has been removed by denudation, while the base may possibly be an irregular and unconformable one upon the underlying Llandeilo rocks. It has not been possible, however, accurately to ascertain whether there is an unconformity here between the Llandeilo and Caradoc rocks, although such a kind of junction may possibly be indicated by the occurrence of the conglomerates, and by the way in which the upper group seems gradually to overlap the lower, from south-west to north-east, on the north-west side of the trough.

31. The Caradoc group appears to nose out between Arbory Hill and the head of Coldchapel Burn, as the latter exposes a section in which the beds of the graptolite zone dip to the south-east, and again rise up without bringing on any higher beds. At Wallace's Cast, on Wandel Burn, a conglomerate is seen, which, from its general appearance and fossil contents, can be pronounced without hesitation to be identical with the conglomerates of Snar water and Kilbucho.* Owing to the want of continuous sections here, the exact relation of this bed to the graptolite zone cannot be made out; but it is presumable that, as in Wandel Burn, opposite Birnock (in the line of strike of the Caradoc zone of Arbory Hill), the beds seen are of the graptolite zone, and nearly vertical. The synclinal axis has there become a mere doubling of the beds together, the graptolite zone being again folded over with a slight dip to the N.W., opposite Rob's Bog, which carries it under the Caradoc conglomerate at Wallace's Cast. Beds containing graptolites are seen above Old Wandel Mill, dipping to the S.E., and this dip continues as far as the foot of Shiel Burn. An unfortunate gap in the section hides the place where the conglomerate is supposed to crop out in this direction.

32. The following fossils have been obtained from the Caradoc rocks of the Leadhills, in the course of the Geological Survey of the district:—

Amorphozoa	Nidulites favus.—*Salter.*	*Polyzoa*	Fenestella sp.
Cœlenterata	Favosites fibrosa.—*Goldf.*		Ptilodictya dicbotoma.—*Portl.*
	—— aspera.—*D'Orb.*	*Crustacea*	Homalonotus (part of axis).
	Petraia bina.—*Lons.*		Trinucleus fimbriatus (portion of shield).—*Murch.*
	—— uniserialis.—*M'Coy.*		Phacops caudatus.—*Brun.*
	—— elongata.—*Phill.*		Cheirurus (fragment).
	Monticulipora lens.—*M'Coy.*		Calymene (eye only).
Echinodermata	Glyptocrinus basalis.—*M'Coy.*		

* Kilbucho is in Sheet 24 of the Geological Survey Map (see the Explanation to that sheet, par. 9). From the collections of fossils which have been made by the Survey from that locality, and from the Wrae limestone, there can be no doubt that these Peeblesshire fossiliferous bands are prolongations of those of Leadhills—that is, of Caradoc or Bala age.

Crustacea .	Oggyia.
Brachiopoda	Leptæna sericea.—*Sow.*
	—— tenuicincta.—*M'Coy.*
	—— transversalis.—*Dalm.*
	Orthis calligramma.—*Dalm.*
	—— var. Wallsalliensis.—*Dav.*
	—— var. Bouchardii.
	—— elegantula.—*Dalm.*
	—— protensa.—*Sow.*
	—— Actoniæ.—*Sow.*
	Strophomena corrugata.—*Portl.*
	—— pecten.—*Linn.*
	—— grandis.—*Sow.*
	—— rhomboidalis.—*Wilck.*
	Atrypa marginalis.—*Dalm.*
	—— hemisphærica.—*Sow.*
	Sprifera plicatella.—*Linn.*
Brachiopoda . .	Meristella angustifrons.—*M'Coy.*
	Rhynchonella.
	Pentamerus oblongus?—*Sow.*
Lamellibranchiata	Ctenodonta (cast).
	Modiolopsis (cast).
Gasteropoda . .	Raphistoma lenticularis.—*Sow.*
	—— elliptica.—*His.*
	Euomphalus.
	Murchisonia.
	Cyclonema sp.
	Turbo.
	Holopella.
	Bellerophon acutus.—*Sow.*
	—— trilobatus.—*Sow.*
Cephalopoda	Orthoceras.

b. Sanquhar District.

33. In that portion of the Silurian area which lies to the south-west of the Nith, the geological structure is less easily traceable than in the Leadhills district. Regarded in a general view, the district now to be described may be taken as occupying a broad synclinal fold, which is a continuation of the great trough of the Leadhills. This fold is interrupted by a minor anticlinal axis in the high ground at the head of the Afton, somewhat in the same way as the Leadhills trough is varied by the occurrence of the arch along the north-west flank of the Lowthers. These two anticlinal folds, however, are not continued into each other, each dying out in an opposite direction, so as partly to overlap the other. In the Sanquhar district also there appear to be other folds, and there is reason to believe that in some cases these folds are actually inverted, so that a series of strata which dip persistently in one direction may be made up of several arches and troughs bent into one uniform inclination, and subsequently much denuded.

34. Beginning at the south-east corner of the district, we encounter the Daer and Dalveen groups in the ravine of the Nith, having a general north-westerly dip. The Haggis Rock group, from the failure of its characteristic conglomerate, is not recognisable there. At Chaulockfoot, on the Scar, some massive conglomerates occur, and a similar rock is seen in the ravine of the Nith at Burnmouth: these appear to be lenticular beds, for they are not traceable for any distance. The group which is most easily followed, and from the convolutions of which the complicated geological structure of the district can best be seen, is that of the Black Shales. As shown on the map, a continuous band of the characteristic anthracitic shale with graptolites can be traced from the Nith, at Burnmouth, for a distance of more than seven miles in a south-westerly direction to the valley of the Shinnel. Wherever these shales occur, they are much crumpled and shattery, and they usually contain bands of very siliceous greywacke. This group of beds, much seamed with veins of felstone, diorite, etc., stretches across the Map from the high ground south of Windy Standard, north-eastward along the right bank of the valley of the Ken, and the hills on the left bank of the Scar Water, striking thence obliquely along the ridge between the Scar and the Euchan to the southern border of the Sanquhar coal-field. On the north-west side of this belt, and rising from underneath it, the Lowther beds appear, and cover nearly the whole of the remaining part of the Silurian area up to the edge of the New Cumnock coal-field. In this tract they are thrown into two folds—one anticlinal, the other synclinal. The former, coming up from

the south-west, strikes through the high grounds near the head of the Afton Water. Its effect has been to bring up a portion of the Haggis Rock group, which is seen forming the crest of the arch along the western slope of Craigbraneoch Rig. As already mentioned, this arch gradually dies out towards the north-east, and the Lowther beds roll over it into the second or synclinal fold just referred to. In the centre of this trough a portion of the Black Shale group is met with, stretching from Auchincally Burn, on the south-west, to the edge of the Sanquhar coal-field at Polmorlach Burn. Between the outcrop of these shales and the great bounding fault, the north-west side of the trough is formed by the Lowther and Haggis Rock groups, which are here best seen in the March Burn dividing the counties of Ayr and Dumfries. It will be observed from the Map that the strike of the Silurian rocks here undergoes a considerable deflection. The Haggis Rock abuts against the boundary fault at the Afton with a N.N.E. strike; but, three miles further on, it again appears on the south side of the fault coming out of the metamorphic area of the Garepool Burn, with a nearly easterly strike, whence it continues to run parallel to the fault for a great many miles to the north-east. The characteristic red and green mudstones of the Haggis Rock group are well seen at Nether Carin and in the Afton.

Metamorphic Rocks in Lower Silurian Series.

35. Throughout the Lower Silurian area embraced in this Map there occur some of those patches so frequent in the Silurian uplands of the south of Scotland, where the strata have undergone local but extreme metamorphism. There appears to be always a close connection between the nature and extent of this metamorphism and the chemical constitution of the rocks in which it is manifested. It is always most developed in those strata into whose composition felspar enters as a main ingredient, while, on the other hand, in the more quartzose rocks little, or comparatively little, change has taken place. From St. Abb's Head to Portpatrick the greywackes are very commonly felspathic, sometimes so much so that they ought rather to be called sandy mudstones. Such rocks have afforded peculiar facilities for the development of metamorphic action; and accordingly we find that it is along their outcrop that metamorphism is chiefly seen. While the whole of the Lower Silurian rocks have undergone a general and comparatively slight alteration, it is only in detached and limited areas that metamorphism has reached an extreme. Of this feature, several characteristic examples occur in the present Map. Two tolerably distinct aspects of metamorphism are here represented. In one of these, the stratified rocks, probably originally more quartzose, have been changed into granite; while in the other, where the strata were probably more felspathic or argillaceous, they have been altered into various porphyries, diorites, etc. The former type of metamorphism is more acidic, the latter more basic; and although the two occur in separate and independent areas, they yet occur together in such a way that sometimes no very sharp line of demarcation can be drawn between them.

36. At the Bail Hill, near Kirkconnel, on the line of outcrop of the Black Shale group, their occurs a remarkable area of metamorphism, covering a space of about three-fourths of a square mile. Owing to the fault which lets down the Sanquhar coal-field, only a fragment of this area is now visible. Round its edges the passage from ordinary greywacke and shale into crystalline amorphous rocks may be traced, while within the crystalline portion there occur beds of mudstone, baked into Lydian stone, but still showing stratification. In one place, at the upper part of the Cat Cleuch Burn, a narrow tongue of hardened, but other-

wise unaltered, rocks, some of which contain graptolites, penetrates the more metamorphosed area, and even in the heart of the crystalline rocks there weather out knobs of comparatively unaltered greywacke or mudstone. The crystalline rocks within this metamorphic patch vary greatly and rapidly in composition. Generally speaking, their matrix is a dull, green, felspathic crystalline-granular mass, through which are dispersed crystals of orthoclase and plagioclase felspar. In some places perfect crystals of hornblende, and others of diallage, mica, and talc, likewise occur, the mica being sometimes so abundant as to form the main mass of the rock. These petrographical changes are so frequent, that it is difficult to find any one name which would suffice to express the general character of this crystalline mass. At different points it might be called quartziferous porphyry, quartzless porphyry or porphyrite, diallage rock, syenite, or even granite. The alteration of the Silurian rocks into these crystalline masses is best seen in the case of the pebbly grits, conglomerates, or breccias; for in such cases the included fragments or pebbles are sometimes little altered, while the surrounding matrix has become coarsely crystalline, abounding in large crystals of hornblende, orthoclase, mica, etc. Reference may be made to Sheet 6 of the Geological Survey of Dumfriesshire, in which this area is mapped in detail. South of Glenmaddie Wood, Euchan Water, a little knob of metamorphosed greywacke is exposed on the hill-side, but is too small to be expressed on the map. The rock has a dull, reddish-green felspathic matrix, with scattered felspar crystals.

37. Reference has already been made (par. 27) to the general but not very intense metamorphism which the shales of group **G** have undergone along their outcrop north-eastward from Craig Dod, between Abington and Crawford. These strata have there been greatly hardened, crumpled, and veined with quartz. In several places, however, there occur limited areas, where the metamorphism has been more pronounced. The prevailing character of the altered rock at these points is that of a dull, dirty green, somewhat decomposed mass, with much diffused serpentine, and breaking up, under the influence of the weather, into small nodular fragments. Here and there it becomes distinctly and sometimes even coarsely crystalline, passing into what might be termed diorite. On Craig Dod the rock is of a dark, purplish grey colour, and abounds in small kernels or grains of quartz (possibly the original pebbles of the greywacke), coated with green earth, among which hornblende crystals are scattered.

38. The second, or granitic, type of metamorphism is well seen along several parts of the north-western margin of the Silurian area. In approaching the localities where it is developed, we find the Silurian strata to become gradually harder, more crystalline, and, in the case of the shales, more schistose, until, after traversing a space from about 100 yards to fully half a mile, we come at last upon the granitic centre. Hence each of these metamorphic areas consists of a central nucleus of granite, with a varying band of altered rocks around it. The largest area is that which is traversed by the Spango Water; it lies on the line of outcrop of the Haggis Rock group and the lower part of the Lowther beds, having a breadth of about two miles and a length of about four. A portion of its northern margin has been cut off by the great boundary fault. Round its margin the more argillaceous shales, which elsewhere are not micaceous, begin to show minute spangles of black mica, which, further into the metamorphic band, increase in number, until they impart a schistose texture to the rock; the colour likewise changes from the ordinary blueish grey of the unaltered districts to a purplish black, owing to the abundance of mica. These superinduced mica-plates have been

developed along the line of bedding of the shales, and the rock splits most easily in that direction, the edge of the fracture, owing to the close grain of the rock, being slightly translucent. Notwithstanding the foliation of these shales, their original bedding can be distinctly traced. It is generally greatly crumpled, the plications being so small as sometimes to be visible on a hand specimen. The red and green mudstones, which appear usually to be more siliceous than the shales, have not undergone foliation. Where they come within the metamorphic area, though they retain very much the same external character as elsewhere, breaking up with their usually shattery fracture, yet they bear evidence of being greatly hardened, while sometimes they have been converted into a kind of coarse Lydian stone or jasper. In the case of the greywackes, pebbly grits, and conglomerates, it is chiefly the matrix of these rocks which has been altered, while the included grains and pebbles of quartz or siliceous rock have remained comparatively unchanged. The matrix probably resembled originally the shales, for it has undergone a similar metamorphism; it abounds in small spangles of mica, which give it a kind of schistose texture.

39. It will be seen from the Map, that, in the case of the Spango granite, as well as in those of the other granitic areas, the Silurian strata strike at the granite on one side, and reappear on the other, without deflection. The granite, therefore, whether we regard it as metamorphic or intrusive, certainly occupies the area once filled by an equivalent mass of Silurian strata. Wherever a junction of the granite and the Silurian rocks is seen, there appears to be a tolerably sharp line of demarcation between the two, no example of an actual passage from the foliated schist into the granite having been met with in any part of the district. At the same time, it is to be noted that in many places they are locked into each other, as it were, by numerous veins, which proceed from the granite, and run chiefly along the bedding planes of the altered rocks. Fragments of the stratified rocks are met with in the mass of the granite, but chiefly along its margin. These are usually angular and oblong, and vary in size from mere "galls" of a finger-length, up to masses ten feet long or more.

40. In the area of the Spango Water and the Garepool Burn the granite is a fine grained mixture of pink orthoclase, with a little oligoclase, quartz, black mica, and hornblende. The quartz, which is second in abundance, is comparatively small in quantity, and the black mica is more plentiful than the hornblende. In the centre of each of these two areas, the granite becomes white in colour and coarser in texture, while the finest grained varieties are those which occur in veins. In each district, also, the granite weathers with comparative rapidity into a rusty coloured sand. The waste is greatest towards the margin of the granite, where the lower general level of that rock shows how much more readily it yields to disintegration than the more prominent altered rocks which rise up around it. A white coarser variety of granite than that already described occurs at the Knipes, the Afton Water near Montraw, and at Cairnsmore, of which a small portion comes into the present Map. Round each of these areas the phenomena of metamorphism above described are well shown, the alteration of the mudstones being specially exhibited round the Garepool granitic boss, and that of the schists round the Knipes; in the latter mass of granite a vein of antimony-glance has been worked, to which reference will be made under the section of economic minerals. It is worth while observing, that while the Spango and Garepool granites come to the surface chiefly in the Haggis Rock group, the granite in the areas now referred to is entirely surrounded by the Lowther beds and a small part of the Black Shale group.

Intrusive Igneous Rocks associated with Lower Silurian Series.

41. It will be seen from the Map that the Lower Silurian area is traversed by many bands of various intrusive rocks. As in other parts of the Silurian uplands of the south of Scotland, these rocks coincide generally with the line of strike of the country, and therefore, though they often cut across the bedding of the shales, etc., they run as dykes, veins, or bands, with a north-easterly and south-westerly direction. It will likewise be observed that, as elsewhere, they tend to occur in groups, being here and there profusely abundant, and then absent altogether for considerable distances. In this sporadic development, they closely resemble the distribution of the more metamorphosed areas. There is ground, indeed, for the conjecture, that both the metamorphism and the intrusive dykes have resulted together from the working of some general cause.

42. The most abundant rock of which these dykes consist is a felstone, which, on a fresh fracture, is usually pale flesh-coloured, but weathers into various tints of yellow or grey. It is a fine granular mixture of orthoclase, with occasionally a little free quartz, sometimes hornblende, more rarely biotite. The quartz occurs in minute granules, which are, however, sometimes as large as peas, or even as almonds. Next in importance to felstone, as a constituent of the dykes or veins, comes diorite. This rock occurs frequently in the south-west part of the Map, where it is seen to consist chiefly of hornblende crystals, diffused through a somewhat decomposed felspar base. Syenite occurs in a larger band, running along the hill-tops from Scawd Law to Rodger Law, a distance of about two miles and a half. It is a coarse-grained rock, consisting of a decomposed felspar, with silvery mica and a little hornblende. It weathers into a pale flesh-colour, and splits into large irregular blocks, the surfaces of which are much decomposed. From its linear direction, this mass is probably an intrusive sheet or vein rising along the line of strike of the greywacke and shale, but its relations to the surrounding strata are obscured by the turf of the hill-slopes. No great alteration is produced by any of these intruded masses upon the Silurian rocks. The shales are sometimes hardened, and even to some extent porcelainized.

43. Among the intrusive rocks may be mentioned one or two small bosses and veins of granite, which rise through a portion of the Lowther group near the head of the Afton Water, but the rocks round these are not so much metamorphosed as round the larger granitic masses already described.

Mineral Veins in Lower Silurian Area.

44. In the high ground round the villages of Wanlockhead and Leadhills, the Lower Silurian rocks are traversed by two systems of mineral veins, the one running N.W. and S.E., the other W.N.W. and E.S.E. These veins contain lead and other ores. Mineral veins have been observed in several other parts of the Silurian area, but not of a kind to offer any prospect of being ever worked for ores. A reference to the mineral veins on the present Map will be given on a subsequent page, under the head of Economic Minerals.

Upper Silurian.

45. Two small areas of this formation occur on the present map, one in the valley of the Greenock Water, the other in that of the Douglas Water. As these are only prolongations of the much larger and more important Silurian tract of Lesmahagow (Sheet 23), their structure will be better understood, by reference to the forthcoming Map and Memoir of that district.

a. Greenock Water District.

46. Bands of hard flaggy shales and grey gritty greywackes are seen in the Greenock Water at Burnfoot. In the same series of strata, in the adjoining Map, *Ceratiocaris* and fragments of *Orthoceras* have been found.

b. Douglas Water District.

47. At Parishholm, near the source of the Douglas Water, is exposed a series of highly inclined blue flaggy shales, containing *Ceratiocaris*, *Orthoceras*, and *Beyrichia*. These strata form the continuation of an anticlinal axis which runs through the Hagshaw Hills (in Sheet 23). The existence of this anticline is not at first easily perceived, owing to an inversion of dip, and to the presence of a large fault, which cuts off the Silurian rocks by bringing down against them sandstones and conglomerates of Lower Old Red Sandstone age. At the back of Parishholm Steading, blue and grey shales, forming the uppermost beds of the series, are seen to dip under a fine conglomerate, which forms the lowest member of the Old Red Sandstone series.

Lower Old Red Sandstone.

48. The area in this Map, occupied by the Lower Old Red Sandstone series, with its accompanying volcanic rocks, is considerable, taking up nearly half of the space lying to the north of the great boundary fault, and is more or less hilly. The rocks, as will be seen, are folded into a series of anticlines and troughs, with a prevailing north-easterly and south-westerly strike. These folds, however, do not affect the surface of the ground; but as the rocks are of very variable hardness and power of resisting the weather, the whole area is denuded into a number of parallel ridges, the harder beds occupying the heights, and the softer ones the valleys. As a rule, the highest ground is that flanking the Silurian uplands, but the greatest elevation attained by any member of the series is in Cairn Table, though the summit of that hill is capped by rocks of Carboniferous age. For convenience of description, the formation, as here represented, has been divided into three zones, which are composed as follows.

49. *Table of the Lower Old Red Sandstone, as developed in this Map.*

C.	12. Chocolate-coloured sandstones, with occasional beds of conglomerate towards their base.	
	11. Conglomerate with pebbles of porphyrite, associated with lenticular beds of purple porphyrite.	
	10. Grey grits and ferruginous yellow sandstones.	
	Average thickness, 5000 feet.	
B.	9. Grey sandstones, tuffs, and beds of shattery melaphyre.	
	8. Purple and greenish slaggy and amygdaloidal porphyrites, and tuffs, becoming split up by intercalations of chocolate-coloured sandstones towards their base.	
	Average thickness, 4000 feet.	

A.
7. Chocolate-coloured sandstones, and thin lenticular beds of conglomerate.
6. Conglomerate with greywacke pebbles.
5. Chocolate-coloured sandstones.
4. Conglomerate with large pebbles of liver-coloured quartz-rock.
3. Green and red mudstones, with bands of grey shale and greywacke.
2. Red mudstones and chocolate-coloured flaggy sandstones.
1. Conglomerate with small pebbles of quartz, Lydian-stone, etc., resting directly upon Upper Silurian shale.

Probable total average thickness of A, B, and C, 15,000 feet.

Group A.

50. This lower group of the Old Red Sandstone of this district is found occupying three separate areas on the present map—viz., along the Douglas Water from Cairn Table to Parishholm; along the northern flanks of Wardlaw Hill; and in the valley of the Greenock Water at the north-west corner of the Map. At each of these localities the group is distinguished from the middle and upper groups, by the entire absence of any intercalated contemporaneous volcanic rocks.

(1.) This band of conglomerate is found resting on the Upper Silurian shales along the side of the Parishholm Reservoir and in the Douglas Water, whence it is continued northwards on the same horizon throughout the Hagshaw Hills (Sheet 23).

(2.) This subdivision follows the line of outcrop of its underlying conglomerate.

(3.) Some of the members of this subdivision show ripple-marked, sun-cracked, and rain-pitted surfaces. They are best seen on the north side of the Reservoir, and in the Douglas Water above Parishholm.

(4.) This peculiar band forms a well-characterized horizon in the Lower Old Red Sandstone from Little Cairn Table northwards into the Lesmahagow district. Its pebbles often exceed eight inches in diameter, and are in many cases dented into each other, indicating the amount of pressure which the rocks of this district have undergone. This and the preceding three subdivisions are only found on the north side of the anticlinal axis, which, striking westwards from the Hagshaw Hills, runs up the Douglas Water and passes underneath Cairn Table. That they are not seen on the south side of this arch, is owing to the presence of a large fault which brings down the sandstones, No. 5. The order of succession, however, can be clearly ascertained from the sections at the reservoir, which show that the strata on the south side of the fault are those which overlie the quartz conglomerate, No. 4.

(5.) Between the quartz conglomerate and another band of conglomerate, No. 6, comes a series of chocolate-coloured sandstones. These run along the south side of the Parishholm fault, and they are likewise seen on the north side of the anticlinal fold, along the slopes of Little Cairn Table which rise above the Muirkirk coal-field.

(6.) This conglomerate differs from all the other conglomerates in the nature of its pebbles, which consist almost wholly of greywacke. It is found on both sides of the arch. The northern outcrop, broken by faults, stretches from near the Blackhill to Auldhouse Burn, whence it turns round the western flanks of Little Cairn Table until it unites with the southern outcrop, which, as is shown in the Map, may be traced continuously into the Hagshaw Hills (Sheet 23).

(7.) The sandstones, which form the uppermost division of the lower group, are best seen at the head of the Duneaton Water, between the conglomerate No. 6 and the base of group B, near North Bottom. In that section they are inclined at an angle of 60°–70°; but westwards, in the Wardlaw Hill tract, they are much less highly inclined, and cover, in consequence, a much larger area.

Group B.

51. The distinguishing characteristic of this group consists in the fact that it is almost wholly made up of contemporaneous volcanic rocks. These are partly lava-form, partly tuffs, and with them are associated other stratified beds, largely made up of volcanic detritus.

(8.) The porphyrites occur in district beds, separated from each other sometimes by intercalations of sandstones and tuffs, sometimes merely by their own slaggy upper and under surfaces. They are usually of a dark purplish or greenish grey colour, close grained, sometimes slightly, sometimes coarsely, porphyritic. They frequently show an amygdaloidal texture, the cavities being lined with green earth, and filled with calcspar, and sometimes with agates. The tuffs are fine grained, well-stratified beds, resembling in colour the porphyrites, from the volcanic detritus of which they have been derived. They occasionally contain bombs of porphyrite. The sandstones interstratified in this division are thicker than the tuffs. Like these, however, they occur as intercalations between the sheets of porphyrite. They consist of a varying mixture of trap debris and ordinary sedimentary detritus. In the Duneaton Water, near North Bottom, they contain worm burrows.

(9.) In this subdivision the characteristic beds are grey sandstones and brecciated conglomerates, composed entirely of trappean debris, and with bands of true tuff interstratified. Among these strata lie thin sheets of dark, heavy, close-grained melaphyre. The latter are sometimes slightly amygdaloidal along the surface of each bed, are much veined with calcspar, and weather into shattery fragments. They are seen at the head of the Glenmore Water, in the Duneaton Water, and the head of the Kennox Water, but they become much more largely developed as they pass north-eastwards into the Douglas district (Sheet 23), while their associated grey sandstones and conglomerates undergo a corresponding diminution.

Group C.

52. In this group, the volcanic rocks, so abundant in the middle division (B), gradually die out, and in its upper part the ordinary chocolate-coloured sandstones, characteristic of the lower series (A), reappear. Hence, in the Lower Old Red Sandstone, as developed within the area of the present Map, we have evidence of the beginning and the ending of a long volcanic period.

(10.) The grits and sandstones of this division have been almost entirely derived from the waste of previously erupted porphyrites. They are best seen in the course of the Duneaton Water, from the foot of Bain's Burn to near the Brown Rig. From that locality, south-westwards they range along the flanks of group B, bending round the anticlinal fold of the latter at Black Law, and running north-eastwards, as a synclinal trough, back as far as the Duneaton Water. As shown on the Map, however, along the south-east side of this trough they are brought down against the porphyrites by a fault.

(11.) This subdivision is made up of massive conglomerates, with occasional lenticular sheets of porphyrite. The conglomerate has been entirely derived from the waste of various porphyrites, its well-rounded pebbles varying from the size of a hazel nut to that of a man's head. This conglomerate forms all the ridges which, flanking the great boundary fault, run in a north-easterly direction from Corsoncone on the Nith to Dungavel Hill on the Clyde; while, on the other hand, the overlying and underlying sandstones have been worn into hollows. As shown in the Map, this band of conglomerate has been thrown into a long synclinal

fold, running parallel with, but sometimes cut off by, the boundary fault. It will be seen that the southern outcrop runs from the northern margin of the Map to the edge of the Spango granite. It is there cut out for a little by the fault, and, on again reappearing, sweeps on continuously to the Nith. The northern outcrop of the trough has been partly concealed by the southern prolongation of the Douglas coal-field. But on the south-west side of that tract it reappears, stretching on to Mountstuart, where, owing to the contraction of the trough, it unites with the southern outcrop. West of Glengaber Hill it again diverges, so as to enclose a long trough of the uppermost subdivision (12). At Corsoncone Hill the southern outcrop of the conglomerate folds over in an arch, which is obliquely truncated by the boundary fault. Here and there, along the strike of this band of conglomerate, there occur intercalated sheets of fine-grained purple porphyrite, exactly similar to that of which the main mass of the stones in the conglomerate has been formed. It will be seen from the Map, that these volcanic rocks occur on both sides of the synclinal trough of conglomerate. It is on the south side, however, that they are chiefly visible; and as they thicken towards the south, we are led to infer that it was from that quarter that they were emptied. No trace, however, has been found of any actual volcanic neck in any part of the Silurian district, unless we may speculate on the possibility of the granitic bosses being in some way connected with volcanic action.

(12.) In this series of chocolate-coloured sandstone we lose all trace of any intermixture of trappean detritus. In the fine conglomerates, which are interspersed through the upper part, the pebbles consist not of porphyrite, but of white quartz. This series of beds is best seen in that part of the trough which is cut through by the Duneaton Water, between Brown Rig and Sheriffcleugh. These are the highest members of the Lower Old Red Sandstone seen in this district of Scotland; but as their uppermost beds have been removed by denudation, no means are left by which to ascertain what may have been here the original thickness of that formation.

Intrusive Rocks in Lower Old Red Sandstone and Upper Silurian.

53. Both these formations are sparingly traversed by intrusive masses of pink felstone. The largest of these is that which stretches from near Muirkirk for some distance to the north-east, and of which only a small portion comes into the present Map. The others are of much smaller extent, being mere dykes and small bosses. The rock of which they consist has a granular base, through which are scattered small granules of free quartz, with occasional mica. Taken in connection with similar intrusive masses to the north-east and south-west of the present Map, these felstones may possibly represent, in some cases, necks from which the porphyrite flows of the Old Red Sandstone were erupted.

Carboniferous.

54. This system of rocks is largely developed in the north-western point of the Map, whence it extends in separate patches down the valley of the Nith. It is here capable of division into the following groups of strata, which can be now recognised over the whole of the Carboniferous area of Scotland:—

Sign on Map.	Groups of Strata.	Localities where seen.
	Coal Measures, consisting of—	
d 5′	(*b.*) Red Sandstones and Clays.	Aird's Moss, Douglas Water, Sanquhar, Kirkconnel.
d 5	(*a.*) White and grey Sandstones, dark Shales, Coal Seams, and Ironstones.	New Cumnock, Lugar, Muirkirk, Douglas, Sanquhar.
d 4	Millstone Grit series.	Lugar, Muirkirk, Kennox Water.
d 2	Carboniferous Limestone series, consisting of white, grey (sometimes red) Sandstones, and dark Shales, with Seams of Coal, Ironstone, and Limestone.	New Cumnock, Glenmore Water, Gass Water, Muirkirk Coal-field, Kennox Water, Sanquhar, Outliers at Wildshaw, Penbreck, and Whiteclengh; Valley of Carron Water and Nith at Drumlanrig.
	Calciferous Sandstone series, consisting of—	
d 1′	(*b.*) Cement-stone Group.	Greenock and Garpel Waters, Water of Ayr.
d 1	(*a.*) Red Standstone Group.	Hilly Ground from Corsoncone to Cairn Table, Water of Ayr at Limmerhaugh, Greenock Water at Netherwood, Douglas and Kennox Waters.

55. For convenience of reference, the Carboniferous rocks will be described here as forming six separate districts on the Map. Of these, the largest, stretching from near the Afton Water northwards to Wardlaw Hill, may be termed the New Cumnock and Guelt district. The area occupying the valley of the Ayr may be called the Lugar and Muirkirk district. Separated from these by the great ridge of Cairn Table, and forming the southern lip of the Douglas basin, is the Glespin district; while detached from it are the outliers of Penbreck, Wildshaw, and Whitecleugh. The coal-field of Sanquhar forms the fifth district, and the sixth lies in the valley of the Carron Water.

a. District of New Cumnock and Guelt.

56. In this district are included all the Carboniferous rocks lying between the great fault bounding the field to the south, and the Glenmore and Guelt Waters. The lowest beds of the series are the Calciferous Sandstones, consisting of red and yellow sandstones and red marls, with concretionary grey sandy limestone or cornstone. The latter rock is considerably quarried at Guelt and Craigdulleart, where large mines have been wrought from time immemorial, the lime being in great demand for agricultural purposes. This cornstone lies near the base of the series, and in some cases rests on the older rocks. It is well seen in the Glenmore and Guelt Waters, in which are exposed good sections of the whole series. The upper part of the series, as seen near Dalblair, consists of very irregularly bedded red tills or fire-clays, with lenticular beds of grey gritty sandstone. These may probably represent the Upper or Cement-stone group. The Carboniferous Limestone series is well developed in this area, and consists of a lower group of sandstones, shales, and limestones; a middle group of sandstones, shales, and coals; and an upper group of sandstones and shale, with bands of limestone, fireclay, and thin coals. The

low limestones are seen at Dalblair and Dornal, where one seam, corresponding to the Gass Water limestone and the 'Hawthorn limestone' of Muirkirk, has been wrought.

57. The coals of the celebrated Edgehill coal-field belong to the Middle series. They lie in the form of a little basin, and their position is proved by the low limestones, which are seen to rise out from below them to the north. The coal seams in this little area are very thick and close together, as will be seen from the following section:—

	ft.	in.
Clay Gas Coal,	1	8
Strata,	10	0
Nine-foot Coal,	9	0
Strata,	16	0
Eleven-foot Coal,	11	0
Strata,	12	0
Twelve-foot Coal,	12	0
Strata,	9	0
Three-foot Coal,	3	0

The strata intervening between the coals vary in thickness, and a little to the east entirely disappear, so that the different coals come together and form a seam forty feet thick. This occurs in a little trough, locally known as the "Ship." The quality and thickness of some of these coals have induced a rigorous search for the reappearance of the seams, but hitherto without success, owing to the borings having been conducted too near the edge of the basin, and consequently through lower rocks. A series of bores, properly conducted along a line from High Polquheys to Laigh Glenmuir, would probably discover them, though the character of the coals would be found to differ from their representatives at Edgehill,—as at Dalfad and Gass Water, where they are known to exist, they have varied considerably. On the other side, bores have been put down through their position at Mansfield, but no workable seams were passed through. In the streams which descend from the Silurian uplands into the Carboniferous Limestone area no coal seams of any thickness are met with; nor, from the conglomeratic character of the deposits there exposed, and the consequent evidence of shore conditions, is it likely that coal seams of any value will be found to occur there. The upper limestones are seen at Mansfield, Polquheys, and at High Park, where they have been long quarried. Polquheys Burn exposes the best section of this series, where a few thin limestones are seen above the main workable one.

58. Overlying the Carboniferous Limestone series come the Coal-Measures, which form the New Cumnock coal-field. The rocks composing this field consist of sandstones, grey shales, fireclays, coals, and ironstones. The succession, in descending order, is given in the following table:—

	fms.	ft.	in.
Lanemark Gas Coal,	0	5	4
Strata,	12–15	0	0
Boig or Lower Gas Coal,	1	0	0
Strata,	8	0	0
Eight-foot Coal,	1	2	0
Strata,	13	3	0
Laird's Coal,	0	3	2
Strata,	4	0	0
Creoch Coal,	0	4	1
Strata,	10	0	1
Coal,	0	3	0
Strata,	4	0	1
Musselband, in several thin beds,			
Strata,	6	0	0

	fms.	ft.	in.
Musselband Coal,	0	3	1
Strata,	1	0	0
Coal,	0	2	1
Strata,	40	0	0

Position of the Black-band Ironstone.

The Black-band Ironstone, the position of which is above mentioned, is the same as that worked at Lugar and Dalmellington, and holds the same horizon as the Slatey-band Ironstone of Lanarkshire. At New Cumnock it is represented by an impure pyritous gas-coal or shale, used for making alum.

There is reason to infer the existence of a large fault stretching east and west, which divides the New Cumnock coal-field, bringing down much higher beds on the south side of the field than those on the north; but it is nowhere seen, owing to its being covered by the alluvium of the River Nith. Many minor faults are found in the coal workings, having a general north-west and south-east direction.

β. Lugar and Muirkirk District.

59. Under this title are included all the Carboniferous rocks lying between Glenmore Water and the north margin of the Map. It embraces the Lugar and Muirkirk coal-field. The lowest beds of the Calciferous Sandstone series everywhere lie unconformably on the older rocks, and consist of a group of red and white sandstones alternating with red and green marly beds, and with occasional beds of grey concretionary cornstone, as in the New Cumnock area. This lower group (*a*) attains its greatest development to the south of the Muirkirk coal-field, and rises in Cairn Table to a height of 1944 feet above the sea. On that hill the red sandstones are very hard and quartzose, and, as they bleach white when exposed to the weather, the resulting fragments are easily recognisable, and hence afford an evidence as to the dispersion of boulders during the glacial period. Good sections of these beds are seen in Gass Water, and all the burns which flow north from the Cairn Table range. The same beds are seen on the Greenock and Garpel Waters, and on the water of Ayr at Limmerhaugh. At these latter places the lower or red sandstone group is overlaid by the upper group of blue clays or tills, with occasional bands of grey and blue impure limestone or cement-stone, and grey gritty sandstones. The cement-stone bands contain *Cyprides* and *Microconchus*. On this side of the field these beds everywhere intervene between the red sandstone group and the Carboniferous Limestone series, but they are not seen on the south side.

60. The Carboniferous Limestone series of Muirkirk is divisible, as at New Cumnock, into three groups—1st, A lower group of sandstones, shales, and limestones; 2d, A middle group of sandstones, shales, coals, and ironstones; and 3d, An upper group of sandstones, shales, and limestones. The position and thickness of the several limestones and coals, with the average thickness of the strata intervening between them, are shown in the section of the Muirkirk coal-field, par. 63. It is possible to distinguish between the different limestones by means of their respective fossils. The following table contains the results of the search made by the Geological Survey into the fossil contents of these beds:—

Table of the Muirkirk Limestones, with their respective Fossils.

Name of Limestone.	Names of Fossils.	Localities of Limestones.
10. Bluetour Limestone.	Rhodocrinus. Athyris ambigua.—*Sow.* —— sp. —— Roysii.—*L'Eve.* Axinus sp. Ctnodonta attenuata.—*Flemg.*	Bluetour, Proscribe Burn, Catchie Burn, Waulkmill.

Name of Limestone.	Names of Fossils.		Localities of Limestones.
10. Bluetour Limestone.	Orthis resupinata.—*Mart.* —— sp. Producta semireticulata.—*Mart.* —— sp. Rhynchonella puguus.—*Mart.* Spirifera bisulcata.—*Sow.* —— lineata.—*Mart.* Streptorhyncus crenistria.—*Phill.*	Ctnodonta gibbosa.—*Flemg.* Bellerophon Urii.—*Flemg.* —— apertus.—*Sow.* Pleurotomaria sp.	Bluetour, Proscribe Burn, Catchie Burn, Waukmill.
9. Thin Limestone.	Cyathophyllum turbinatum.—*Goldf.* Actinocrinus sp. Platycrinus sp. Poteriocrinus crassus (?)—*Miller.* Phillipsia Derbyensis (?)—*Martin.*	Fenestella plebeia.—*M'Coy.* Athyris sp. Producta gigantea.—*Mart.* —— costata.—*Sow.* Orthis resupinata.—*Mart.* Axinus carbonarius.—*Portl.* Bellerophon Urii.—*Flemg.*	Garpel Water.
8. Tibby Pagan's Limestone.	Calamites Suckowii (in shale).—*Brong.* —— sp. (,,).		Garpel Water, Auldhouse Burn.
7. Limestone,			Garpel Water.
6. Limestone,			Garpel Water.
5. Ell Coal Limestone,			Garpel Water, Auldhouse Burn.
4. Macdonald Limestone, & 3. Limestone.	Cyathophyllum turbinatum.—*Goldf.* Lithostrotion. Actinocrinus. Poteriocrinus crassus.—*Miller.* Athyris ambigua.—*Sow.* Orthis resupinata.—*Mart.* Producta gigantea.—*Mart.* —— latissima.—*Sow.* —— longispina.—*Sow.* —— semireticulata.—*Mart.* —— costata.—*Sow.* Spirifera bisulcata.—*Sow.* —— striata.—*Mart.* —— trigonalis.—*Mart.* Axinus carbonarius.—*Portl.* Bellerophon Urii.—*Flemg.* Orthoceras.		Wellwood Burn, Garpel Water, Bankend, Auldhouse Burn, Crossflatt, Ashaw Burn, Water of Ayr near Wellwood Row.
2. Hawthorn Limestone.	Cyathophyllum turbinatum.—*Goldf.* Lithostrotion irregulare.—*Phill.* Amplexus coralloides.—*Sow.* Athyris sp. Producta gigantea.—*Mart.* —— latissima.—*Sow.* —— longispina.—*Sow.* —— semireticulata.—*Mart.* —— costata.—*Sow.* Orthis resupinata.—*Mart.* Spirifera glabra.—*Mart.* —— bisulcata.—*Sow.* —— striata.—*Mart.* Avicula Verneulii.—*M'Coy.* Aviculopecten alternatus.—*M'Coy.*		Wellwood Burn, Garpel Water, Springhill, Bankend, Auldhouse Burn, Crossflatt, Ashaw Burn, Darnhaunch, Tordoes.
1. Wee Limestone,			Auldhouse Burn, Ashaw Burn, Darnhaunch.

61. The Millstone Grit which overlies the Carboniferous Limestone series is well seen at Muirkirk, where it occurs as coarse white and yellow friable grits and sandstones, with seams of fireclay and thin coal. It

occurs also in the Lugar Water at Wallacetown, but is there much thinner than at Muirkirk, and its outcrop is still further narrowed by the intrusion of a large basaltic mass.

62. A very small portion of the Coal-Measures constituting the Lugar coal-field comes into the present Map, as may be seen by the outcrop of the black-band ironstone; but as this field has already been described, and a section of it given in par. 55 of the Memoir accompanying Map 14 of the Geological Survey, reference may be made to that publication. It will be seen from the present Map, that a detached portion of the Coal-Measures forms the western extension of the Muirkirk coal-field; and, owing to the quantity and quality of the coal seams, they have been extensively worked at Nether Wellwood Colliery. The black-band ironstone has been the main object of search. It is the same as that worked at Lugar and Dalmellington. A section of this field is exposed in the Powharnal Burn, along the sides of which most of the coals have been worked open-cast. The red sandstone group, which forms the uppermost part of the Coal-Measures, is seen at Nether Wellwood, on the Powharnal Burn. It consists of purple sandstones and shales very much crumpled, their disturbance being probably due to their proximity to a large fault, which brings them down against low members of the Carboniferous Limestone series. The coals of this field are in many places destroyed by thin intrusive sheets of white trap, and they are further traversed and altered by a number of trap dykes and volcanic necks.

63. *Muirkirk Section.*

		fms.	feet.	in.
Coal-Measures	Coal,	0	2	6
	Strata,	2	0	0
	Coal,	0	5	0
	Strata,	11	0	0
	Three-foot Coal (Claud),	0	3	3
	Strata,	9	0	0
	Seven-foot Coal (Maid),	1	1	0
	Strata,	0	3	0
	Coal (Low Maid),	0	3	0
	Strata,	18	0	0
	Coal,	0	2	4
	Strata,	21	0	0
	Musselband Ironstone,	0	0	6
	Strata,	3	0	0
	Five-foot Coal,	0	5	6
	Strata,	3	0	0
	Six-foot Coal,	0	6	6
	Strata,	23	0	0
	Black-band Ironstone,	0	1	0
	Strata,	10	0	0
	Thin Black-band,	0	0	6
Millstone Grit	Strata consisting chiefly of Sandstones, Grits, Fireclays, and Thin Coals,	140	0	0
Carboniferous Limestone Series	10. Bluetour Limestone,	8	4	0
	Bluetour Coal,	1	2	0
	Strata,	10	0	0
	9. Limestone,	0	2	0
	Strata,	15	0	0
	8. Tibby Pagan's Limestone,	0	6	2
	Strata,	12	0	0
	Cokeyard Coal,	0	3	6
	Strata,	13	0	0
	7. Limestone,	0	4	0
	Strata,	8	0	0
	6. Limestone,	0	1	3
	Strata,	5	0	0
	5. Ell Coal Limestone,	0	2	3
	Strata,	6	0	0

		fms.	feet.	in.
Carboniferous Limestone Series	Ell Coal,	0	4	0
	Strata,	0	4	0
	Black-band Ironstone,	0	0	10
	Strata,	6	0	0
	Seven-foot Coal,	1	5	2
	Strata,	5	0	0
	Nine-foot Coal,	1	1	6
	Strata,	5	0	0
	High-band Ironstone (Clay),	0	1	2
	Strata,	5	0	0
	Mid-band Ironstone (Clay),	0	1	3
	Strata,	1	0	0
	Thirty-inch Coal,	0	2	6
	Strata,	5	0	0
	Six-foot or Catchybun Coal,	1	0	0
	Strata,	8	0	0
	Low-band Ironstone (Clay),	0	1	0
	Strata,	2	0	0
	M'Donald Coal,	0	5	0
	Strata,	2	0	0
	M'Donald Ironstone (Clay),	0	1	2
	Strata,	0	2	0
	4. M'Donald Limestone,	6	0	0
	Strata,	5	0	0
	Smith Ironstone (Clay),	0	0	4
	Strata,	2	0	0
	3. Limestone,	0	3	0
	Strata,	0	2	3
	Crossflatt Ironstone (Clay),	0	0	6
	Strata,	3	0	0
	2. Hawthorn Limestone,	3	3	6
	1. Wee Limestone,			
	Calciferous Sandstone Series,			

64. *Gass Water Section.*

	fms.	feet.	in.
Limestone,	0	6	0
Strata,	3	1	6
Limestone,	0	1	6
Strata,	2	0	0
Limestone,	0	5	0
Strata,	2	0	0
Coal,	0	2	6
Strata,	0	2	2
Coal,	0	2	4
Stone,	0	0	10
Coal,	0	0	9
Stone,	0	0	9
Coal,	0	3	0
Stone,	0	0	6
Coal,	0	1	3
Strata,	8	0	0
Coal,	0	2	0
Strata,	0	1	2
Coal,	0	1	3
Strata,	1	0	0
Smithy Coal,	0	1	8
Strata,	3	0	0
Clay Ironstone,	0	0	10
Strata,	1	3	0
Coal,	0	2	0
Strata with Ironstone,	1	2	0
Coal,	0	1	0
Strata,	3	0	0
Limestone,	1	5	7

γ. Glespin or Douglas Water District.

65. As shown on the Map, this district has a rudely triangular shape: the base of the triangle is formed by the somewhat irregular and

faulted overlap of the carboniferous rocks upon the Old Red Sandstone, while the two sides are bounded each by a fault which brings these two formations together.

66. The lower or red sandstone group of the Calciferous Sandstone series is found in the south-western part of the district in the Kennox and Carmacoup Waters. The bottom on which these strata were deposited must have been remarkably irregular, for it will be observed that, in a space of little more than a mile, the sandstones of the Kennox Water, which may be about 500 feet thick, die out altogether, and the Carboniferous Limestone series rests directly on the Old Red Sandstone. Nor is this thinning out confined to the Calciferous Sandstones: the lower part of the Carboniferous Limestone series has also disappeared. In connection with this point in the physical structure of the district, it is interesting to observe, that where the carboniferous rocks rest upon the Old Red Sandstone, their lowest beds consist of conglomerate made up from the waste of the older formation, and that these conglomerates continue to fringe the carboniferous area, while the strata above them pass quite away. Hence, in this continuous band of conglomerate, one portion is on the horizon of a low part of the Calciferous Sandstone series, while another portion is on the horizon of some of the higher members of the Carboniferous Limestone series. It thus brings before us evidence of shore conditions during a protracted submergence of this area in Lower Carboniferous times.

67. The Carboniferous Limestone series, where most fully developed in the Kennox Water, resembles that at Muirkirk. The lower limestone and clay-band ironstones, in particular, are readily recognisable. Coal seams likewise occur, which, although probably the equivalents of those at Muirkirk, are yet not easily determined, owing to the absence of good natural sections and the want of any borings. As already remarked, the Limestones series undergoes considerable modification in its passage from west to east. The lower limestone group, so well developed in the Kennox Water, dies out entirely in about a mile. It is the uppermost limestones which are seen in Glentaggart Burn; yet, notwithstanding this rapid attenuation, the basement conglomerate above described continues to be seen wherever a section has been cut by a water-course.

68. The Millstone Grit is here well developed, and gives rise to a series of not inconsiderable hills. It is best seen in the Kennox Water, where it consists of sandstones, which in their lower part are yellow, coarse-grained, and friable; and in their upper part contain fireclays and thin coals, of which latter, however, one seam is four feet thick.

69. The Coal-Measures of this district contain all the coals at present wrought here: the position and thickness of the several seams are shown in the subjoined section. The upper group of red sandstones is seen in the bed of the Douglas Water at Mavisbank School.

Glespin Section.

		fms.	ft.	in.
Coal-Measures	Seven-foot Coal,	1	1	0
	Strata,	6	0	0
	Musselband Ironstone,	0	0	11
	Strata,	8	0	0
	Four-foot Coal,	0	4	2
	Strata,	11	0	0
	Nine-foot Coal,	1	2	6
	Strata,	6	0	0
	Foul Dross Coal,	0	4	0
	Strata,	10	0	0
	Dross Coal,	0	2	10
	Strata,	40-50	0	0
	Black-band (Slatey-band) Ironstone (not workable as an Ironstone here),	0	0	0

The extent to which this field is faulted will best be seen by a glance at the Map. In addition to the two boundary faults already referred to, the southern outcrop of the district is broken by three dislocations. Of these, the most important is that which, diverging from the great boundary fault, strikes northwards parallel to the line of the Glespin Water: its effect has been to let down the Glespin coal-field against the Carboniferous Limestone series on the east.

δ. Outliers of Moss Burn, Penbreck, Wildshaw, and Whitecleuch.

70. That the Carboniferous rocks once extended over a much larger area than they now cover, is shown not only by the denudation so clearly marked by the outcrop of the strata in the several districts, but by the occurrence of small outliers, lying sometimes far away from the main mass of the formation to which they belong, and of which they once formed a part. Of these outliers, the largest is that which lies in the Duneaton valley at Whitecleuch. At its southern end it rests unconformably on the Lower Silurian rocks; while on either side, and at the north end, it is brought down by faults against the older rocks. The bottom beds are fine conglomerates, which, as they lie below the lowest limestone, are presumed to belong to the Calciferous Sandstone series. The main portion of the outlier, however, consists of a portion of the Carboniferous Limestone series. As the limestone which is seen at the north end close to the boundary fault is one of the upper limestones, we may infer that the whole of the Muirkirk section, except the Coal-Measures, is here represented. The M'Donald coal only has been worked.

71. At Wildshaw, on the northern edge of the Map, a small outlier of the Hawthorn limestone of Muirkirk rests almost directly upon the Old Red Sandstone, being separated from it by only a few yards of friable sandstone and conglomerate. In this instance, also, we see that the whole of the Calciferous Sandstone group is wanting. The eastern side of this outlier is bounded by a fault.

72. At Penbreck, a shepherd's house, near the source of the Glenmore Water, a little Carboniferous basin is found, of which the margin is to a large extent bounded by faults. Its lower portion contains the Hawthorn and M'Donald limestones of Muirkirk, above which lie some of the lower coal-seams of that field. It will be seen from the Map, that along the side of the same fault, which bounds this outlier on the south, there occurs a small outlier of Calciferous Sandstone close to the edge of the Glespin coal-field, and that this fault is one of those by which the southern margin of that field is broken.

ε The Sanquhar Coal-field.

73. With the exception of the small faulted outlier at Whiteclengh, all the Carboniferous districts described in the foregoing pages lie to the north of the great boundary fault, and therefore outside of the Silurian region. The districts which remain to be described lie wholly within the Silurian uplands. In tracing their outlines, we soon learn that the Carboniferous rocks have been deposited in ancient hollows or valleys, which, worn out of the Silurian rocks in palæozoic times, were afterwards filled up with Carboniferous and Permian deposits, and in long subsequent ages were re-excavated, so as now to present the form of valleys and hollows once more. In the course of this protracted denudation so much of the original Carboniferous and Permian covering has been removed, that only fragments of it are now left; while the Silurian floor, on which it was laid down, has been everywhere, and often deeply, eroded. Enough,

however, remains to show us, that what is now the valley of the Nith was also a valley in Carboniferous times, and that somewhere about the site of Kirkconnel lay the head of this valley in the form of a col, from which the ground descended northward, with probably an abrupt slope, into Ayrshire. In proof of this statement, we find that, in ascending the Nith valley, the Carboniferous Limestone series, which is so well developed in the Thornhill basin, thins out towards the north, until along the south-eastern borders of the Sanquhar coal-field it disappears altogether, and the overlying Coal-Measures come to rest directly on the Lower Silurian rocks. No Carboniferous Limestone beds reappear until we reach the great fault, immediately on the north side of which they come in in force. It is difficult to understand how this should have happened, unless on the supposition that, at the time when the Carboniferous Limestone series was in the act of deposition, the line of fault was represented at the surface by a steep bank shelving to the north, which formed the limit of the Limestone series on that side, but which, as the whole region continued to sink, was gradually buried under the continuous sheet of Coal-Measures which stretched through the Sanquhar valley northwards into Ayrshire.

74. Of the remaining fragments of the Carboniferous deposits once laid down within the Silurian area, the largest and most important forms the Sanquhar coal-field. As shown on the Map, this area covers a part of the Nith valley, about nine miles long, and from two and a half to four miles broad, with the river flowing down its centre. On the left bank of the Nith the boundary of the coal-field is formed by a long and powerful fault, while on the right bank the edge of the field is defined by the line of the outcrop of the lowest bed of the Coal-Measures upon the Silurian rocks. At the south-eastern end of the field several small outlying patches of the Carboniferous Limestone series occur. They consist, at the base, of fine conglomerate, covered by sandstones, shales, and thin concretionary fossiliferous limestones. At Brandleys a portion of the same rocks is seen passing underneath the Coal-Measures, whence it may be inferred that only the upper part of the Carboniferous Limestone series is here represented.

75. The Sanquhar coal-field is entirely made up of strata belonging to the true Coal-Measures. Although it has not yet been possible to identify many of the coal-seams of this field with those in the neighbouring district of New Cumnock, yet, from the general resemblance of the other strata in the two coal-fields, there can be little doubt that they have at one time been connected, and therefore that the Sanquhar coal-field is only a prolongation of the Ayrshire Coal-Measures.

Sanquhar Section.

		fms.	ft.	in.
Coal-Measures	Creepie Coal	0	2	7
	Strata	7	0	0
	Calmstone Coal	0	4	1
	Strata	11	0	0
	Twenty-inch Coal	0	1	8
	Strata	40	0	0
	Daugh Coal	0	4	7
	Strata	50–60	0	0
	Splint Coal	0	5	0
	Strata	16	0	0
	Swallow-Craig Coals: Coal	0	1	5
	Strata	3	0	0
	Coal	0	1	10
	Strata	6	0	0
	Coal	0	1	2
	Strata	30	0	0
	Position of (Slatey) Black-band Ironstone.			

On the north-east side of the field lies a portion of the upper barren red sandstones, which here, as in Ayrshire, overlap the older portions of the Carboniferous system. The interval between their deposition and that of the highest part of the underlying Coal-Measures is further shown by the fact that at one place, near Bankend, they actually spread over a fault in the Coal-Measures of ninety fathoms without being themselves disturbed. Yet that these red sandstones are of Carboniferous and not of later age, is indicated by the occurrence in them of at least two coal seams (one of which is two feet thick) and one of black-band ironstone, which are seen in the stream near Kirkland. Overlying the red sandstones at the south-east end of the field are three small outliers of melaphyre, which, from their position and their petrographical character, must be placed on the same horizon with the Permian volcanic rocks of the Carron Water, to be afterwards described, and with the corresponding Permian volcanic rocks of Ayrshire. They are mere fragments of lava flows; and some of the points of eruption from which they were ejected are still visible in the necks of agglomerate which rise through the coal-field.

76. Of the faults by which the Sanquhar coal-field is bounded and intersected, by far the largest is that which has let down the coal-field on the north-east side against the Silurian rocks. From the depth of Coal-Measures which it throws out at the north-east or deepest part of the field, it must be one of at least 1200 feet. Its most singular feature, perhaps, is the remarkable bend which it makes when, in proceeding to the north-west, it approaches within less than fifty yards from the great boundary fault. Instead of touching that dislocation, it turns off sharply to the left, and runs parallel with it for two miles, the space between the two faults being sometimes not more than twenty yards. The line of the fault is made conspicuous even at the surface, from the fact of its having been taken by a massive dolerite dyke which extends along the fault for several miles on both sides of the angle. About a mile and a half beyond the angle, on the north-west side, this dyke cuts across the narrow intervening strip of Silurian strata into the great boundary fault, along which it continues to run until it is lost under the alluvium of the Nith. Parallel, in a general sense, with the fault which has just been described, a number of minor dislocations traverse the coal-field, with the effect of letting down the beds by a series of steps towards the north-east or deepest part of the field. Of these, the largest has been already referred to as having a throw of ninety fathoms. It runs in a N.N.W. direction, and, as shown by the workings in the Bankhead Colliery, brings down the Calmstone coal against the Splint coal seam. Yet, as before remarked, it does not penetrate the overlying red sandstones, the whole of the displaced rock on the upthrow side of the dislocation having been removed by denudation before these strata were deposited.

One distinguishing feature in the Sanquhar coal-field is the fact that along the south-west half of the field the strata are traversed in a north-westerly direction by at least three narrow doleritic dykes, which send out intrusive sheets along the coal seams. The trap itself is much decomposed, having the same character as the white trap so common in the Ayrshire coal-fields.* As in Ayrshire, the coals are so altered by it as to be unworkable. In some places they have been converted into beautifully columnar anthracite.

ζ. Carron Water Basin.

77. A little to the south-east of the Sanquhar field, the Carboniferous Limestone rocks, which appear as mere thin detached fragments near Sanquhar, come in much more strongly in another of the ancient de-

* See *Explanation of Sheet* 14 of the Geological Survey of Scotland, p. 22.

pressions already described. While they have been removed entirely out of the intervening portion of the Nith valley, they are still preserved in the valley of the Carron Water, which then, as now, was a tributary of the Nith. This side valley runs still, as it did in Carboniferous times, deep into the flanks of the Lowther Hills. Its bottom is covered with Carboniferous and Permian rocks, which, sweeping southwards into the Nith valley, expand over the basin of Thornhill. Along the whole of the west side of the Carron Water valley the Carboniferous rocks rise from under the Permian. On the east side, however, they are seen only here and there, owing to the way they are overlapped by the later formation.

78. In the southern part of the Thornhill basin the limestones of Closeburn contain characteristic Carboniferous Limestone fossils. They are associated with red sandstones and red shales, which, stretching northwards, appear to belong to the same group of strata as those which on the present Map are represented as rising from under the Permian rocks of the Carron Water basin. It has therefore been necessary to colour the whole as Carboniferous Limestone. At the same time, it must be noted that the Carboniferous rocks in the Carron Water area are undistinguishable from the red upper Coal-Measures of Sanquhar and Ayrshire. No trace, however, of any undoubted Coal-Measure strata has yet been detected here; and, in the absence of other evidence, the whole of the Carboniferous rocks of the Thornhill basin are grouped, with the limestones of Closeburn, under the Carboniferous Limestone series.

79. Many good sections are to be seen of the Carboniferous rocks between Drumlanrig and the north end of the basin, particularly in the ravines which have been cut through them by the Nith, and also along the course of the Enterkine Burn, and in the railway cutting at the north end of the Drumlanrig Tunnel. The whole series of rocks strata is about 500 feet thick, resting unconformably on the Lower Silurian rocks (as beautifully seen in the ravine of the Nith at Duncan's Linn), and overlapped by the porphyrites of the Permian series. They consist of red and reddish grey sandstones, and lilac or mottled clays and shales. They occasionally, as at Duncan's Linn, contain *Stigmaria* and other plant remains.

Intrusive Rocks in the Carboniferous Series.

80. The Carboniferous groups represented on this map are traversed by three forms of igneous rocks—sheets, necks, dykes. 1. The largest intrusive sheets are those which have been injected along the horizon of the upper limestones, New Cumnock and Aird's Moss. Others on a smaller scale occur among the upper coals in the New Cumnock field, and likewise in the Sanquhar district. All these sheets consist of basalt-rocks. 2. Necks marking the position of former volcanic vents occur in different parts of the Carboniferous district, and are probably all of Permian age. They consist of pipes which descend vertically, and are filled up with various fragmentary materials, which were ejected from the orifice by volcanic action, and subsequently fell back into it, and were consolidated there. Five of these necks occur in the Sanquhar coal-field: four are shown on the Map as occurring in the Muirkirk area, while another occupies a position on the Old Red Sandstone at the north-west corner of the Map. The latter is the only example in this Map of a neck occurring in any other than a Carboniferous area. 3. The Carboniferous tracts, like the rest of the area embraced in the present Map, have been invaded by many of the remarkable north-west and south-east dolerite dykes by which the south of Scotland is so much traversed. These dykes will be more particularly referred to in par. 88.

Permian.

81. In two separate areas of the present Map are shown certain strata which are referred to the Permian system. Of these, the one is an extension northward of the basin of Thornhill (Sheet 9); the other lies near the northern edge of the Silurian region between Leadhills and Crawfordjohn. Both these areas of Permian rocks occupy hollows in the Silurian uplands, and, taken in connection with the Carboniferous outliers already described, they show at how early a date these uplands had undergone extensive denudation, and had been worn into valleys. The hollows in which the Carboniferous and Permian strata were deposited were no doubt, in great measure, if not wholly, filled up and obliterated by these deposits, which have since been cleared out again, so as to expose, though in a worn and fragmentary state, the original valleys of Carboniferous and Permian times. That the rocks occupying these hollows are referable to the Permian system, is inferred from the following facts:—1*st*, They overlie the Carboniferous series unconformably; 2*d*, They are, to a large extent, identical with strata which unconformably overlie the Coal-Measures in Ayrshire; 3*d*, They are the same as those which, in the Dumfriesshire basin, pass southwards under the Trias of Cumberland.

a. Carron Water Basin.

82. This area extends along the valley of the Carron Water northwards to the mouth of the Pass of Dalveen. While merely a prolongation of the Permian basin of Thornhill, the rocks in the valley of the Carron Water differ from those of the same series further south, in the greater abundance of volcanic rocks, and of volcanic detritus in the sandstone. The whole of the Permian series of the Carron Water basin is full of evidence of contemporaneous volcanic activity, while southwards this evidence dies out, and in the centre and south of the Thornhill area ceases to be traceable. The following, in descending series, is the succession of rocks along the Carron Water:—

b. Brick-red sandstones full of trappean detritus, and with bands of trap-tuff, and occasional thin sheets of porphyrite.
a. Porphyrite, in different beds, resting on the Carboniferous series.

83 (*a*). The lower division of the Permian series here consists of various beds of porphyrite and melaphyre, which rise from under the brick-red sandstones, and form a marked ridge between these and the underlying Carboniferous rocks along the west side of the basin. On the east side they are partly overlapped by the red sandstones, and do not there form so striking a surface-feature as on the other side. The trap-rocks have a general dull purple or purplish grey or chocolate-brown colour. They vary from a finely crystalline compact form to an earthy amygdaloid or an open scoriaceous rock. In the amygdaloids, steatite abounds in the cavities and cracks. All of these rocks appear to consist of a base of triclinic felspar, to which titaniferous iron, augite, and in particular a red ferruginous decomposed mineral, are added in various proportions. In most cases they are probably most properly classed under the general term porphyrite, though, in some cases where the augite and titaniferous iron are conspicuous, they could not be separated from melaphyre. They perfectly resemble the Permian volcanic rocks of Ayrshire.*

84 (*b*). Above the porphyrites comes a conformable series of brick-red sandstones and tuffs, forming the basement beds of the Thornhill basin.

* See *Geological Magazine* for June 1865, and *Memoirs of Geological Survey, Explanation of Sheet* 14, p. 22.

The whole of this series of rocks is more or less marked by the diffusion through it of trappean detritus, sometimes in the form of minute grains, sometimes as a gravelly intermixture, sometimes in large blocks and trappean bombs, sometimes in regular interstratified bands of trap-tuff. Occasionally, as at Durrisdeer Mill, a band of porphyrite is intercalated in the series. As shown on the Map, a slight roll of the porphyrite series suffices to separate the overlying sandstones into two distinct areas, of which the northern forms an independent outlier, while the southern passes onwards into the Thornhill tract. It is in the former that the evidence of contemporaneous associated volcanic action is most conspicuously exhibited, as shown by the section in the Carron Water from the Railway Viaduct north to near Nether Dalveen. To the south of the viaduct the sandstones are less strongly intermingled with trappean detritus, and begin to assume the characteristic brick-red colour and false-bedded stratification, so well seen in the streams and quarries to the east of Thornhill.

85. In connection with the volcanic sheets of this district, reference may here be made to the necks which occur to the north-west in the Sanquhar coal-field, and dot the Aird's Moss and Muirkirk coal-field. These, there can be little doubt, mark the site of volcanic orifices in Permian times; and as they continue through Ayrshire up even into Renfrewshire, they show how abundant volcanic action was in the south-west of Scotland during the later palæozoic periods.*

β. Crawfordjohn District.

86. Between the villages of Leadhills and Crawfordjohn there occurs a singular detached area of breccia about a mile broad and two miles long. It fills a depression in the Silurian rocks, and may once have stretched into and along the Duneaton valley, which, as we have seen, is filled at Whitecleuch with Carboniferous deposits. From the similarity of this breccia to some of those in Annandale, it is inferred to be of Permian age. It has been entirely derived from the waste of the surrounding Lower Silurian rocks, no fragment of Old Red Sandstone or conglomerate or of any Carboniferous rock having yet been recognised in it. The stones are angular and subangular, often of a somewhat flat form, and vary in size up to a foot or more in length. They strongly resemble the form of the stones in boulder-clay or moraine rubbish. Indeed, where the usual stratification of the mass fails to appear, and the stones have been thrown together irregularly, the resemblance to a glacial deposit is very striking. The stones are commonly crusted with a thin coating of hæmatite. A careful search was made among them for striated surfaces, but without success. The paste of the mass is scanty, and occurs as a red, sometimes green, sandy clay. No rock like this breccia occurs anywhere in the Old Red Sandstone series of this region, though it sometimes resembles part of the upper Old Red conglomerate of the Lammermuirs. Nor is there anything analogous to it in any part of the Carboniferous area. It quite resembles, however, some of the coarse Permian breccias near Moffat, though on a much larger scale. In the absence of other evidence, therefore, it is classed with these as Permian.

Igneous Rocks of Miocene Age.

87. The present Map contains several excellent examples of the system of dolerite dykes, which were probably erupted during the Miocene period. These are shown, by the long narrow parallel stripes of crimson on the Map, to have a prevailing N.W. and S.E. direction. They do not run in

* See *Explanation of Sheet* 14, p. 22.

absolutely straight lines, but their irregularities of outcrop are to a considerable extent due to the inequalities of the ground, and to the fact that the dykes, instead of being vertical, sometimes have a very considerable inclination or hade to one side. Each dyke retains a singular uniformity of breadth, the larger ones averaging from fifty to sixty feet wide, with sharply defined wall-like sides. It will be seen that these dykes cross every other rock in the district; and not only so, but even large faults which they cut without the slightest deviation. This is particularly to be noticed in the case of three dykes in the neighbourhood of Crawfordjohn, which pass without deflection or alteration across the enormous boundary fault. Yet the dykes have not themselves risen along lines of fault. The clean cut fissures through which they have come show no elevation or depression of the beds on either side of them. The two dykes which completely traverse this Map have each been traced for many miles to the N.W. and S.E.*

Faults.

88. Two series of faults occur on this Map: the first and most powerful runs from S.W. to N.E., while the others run more or less perpendicular to them, viz., in a N.W. and S.E. direction. Reference has frequently been made in the course of the foregoing pages to the great boundary fault which separates the Silurian uplands from the Old Red Sandstone and the Carboniferous tracts on the north. It is a continuation of the great fault described in the Explanation to Sheet 14, and continues in the same straight line north-eastwards across the present Map for many miles, until it is overlapped by the Mid-Lothian coal-field. From the detailed survey which has been made of the Old Red Sandstone, it is possible to estimate the amount of throw which the fault has here. We know the thickness of that formation to be fully 15,000 feet, and the fault must be a dislocation to that amount at least. It is also evident that this great dislocation is older than the Carboniferous period, although it may very possibly have served subseqnently and often as a line of weakness along which movements afterwards took place. This is shown by the entire absence of any Old Red Sandstone on the south side of the fault, and by the occurrence of the Carboniferous Limestone and Coal-Measures lying directly on the Silurian rocks. So vast a thickness of Old Red Sandstone could not have ended originally where the fault now is, but must have swept southwards over the Lower Silurian uplands. Yet these thousands of feet of sandstones, conglomerates, lavas, and tuffs were so completely removed from the south side of the fault previous to the deposition of the Carboniferous Limestone series and the Coal-Measures, that not a fragment of them is anywhere to be seen between these later formations and the Old Silurian floor. That the fault continued to be a line of weakness along which movements took place in Carboniferous or later periods, is proved by the way in which the Carboniferous Limestone series is brought down by it against the Silurian region to the south of New Cumnock. We have other evidence to the same effect in that remarkable curving fault, which has been already described as running at the north-west end of the Sanquhar field, parallel with and close to the great boundary fault. A similar inference may be drawn from the position of the faulted outlier at Whitecleuch. Several other N.E. and S.W. faults lie to the west of the large one; but these are of much less antiquity and of less extent, seeing that their utmost effect has been to bring down the Coal-Measures against the Lower Old Red Sandstone.

89. The second or N.W. and S.E. series of faults, although much

* For further information regarding Miocene dykes, see *Explanation of Sheet* 14 of the Geological Survey of Scotland, and the references there given.

more numerous, are far less powerful than those in the opposite direction. They are cut off by the latter, and are seldom traceable for more than a mile or two.

90. It will be seen that most of the faults represented on the Map lie in the coal-fields. In the Muirkirk field the largest throw is one of sixty fathoms, the general effect of the faults there being to throw down the strata towards the S.W. The fault, however, which skirts the northern margin of the Old Red Sandstone area of Wardlaw has a downthrow towards its western extremity of at least 400 fathoms to the north. In the Sanquhar field, also, the faults belong almost wholly to the N.W. and S.E. series. Their general effects have been already referred to in par. 76.

Drift.

91. Evidence of the former movement of ice over the country is well displayed in several parts of the area embraced in this Map. This evidence consists of *Scratched Rock-surfaces*, *Boulder-clays*, *Sands and Gravels*, *Erratic blocks* and *Moraines*.

92. **Scratched Rock-surfaces.**—Beneath the covering of superficial accumulations, and on bare hill-sides, from which these deposits or the coating of turf have been removed, the worn, polished, and striated surfaces, characteristic of ice-action, are found in many places. As the result of the observations made in the course of the Geological Survey, it appears that the high grounds, ranging from the sources of the Afton north-eastwards through the Lowther and Leadhills to the Clyde, have served as a central axis of dispersion for the ice of the glacial period. This is shown by the fact that the striæ on the rocks diverge from this axial line to the low grounds on the north and south. As the range of high grounds was traversed then, as now, by the valley of the Nith, there would necessarily be a point or pivot in that valley, from which the ice would move in opposite directions. This is borne out by the direction of the striations on the rocks, of which the more important of those observed are marked on the Map.

93. **Boulder-Clays.**—These clays are of the usual stiff, coarse, stoney character, quite unstratified, and differing in colour and composition locally, according to the nature of the rocks of each district. Among the Silurian hills they are dull grey or fawn-coloured; on the Old Red Sandstone tracts they are dark brown or red; while over the Carboniferous areas they are of a black or dark leaden-blue tint. Though it is possible to recognise that there is a stiff lower boulder-clay, and a loose, more gravelly, upper boulder-clay, these cannot well be separated in mapping. The evidence yielded by these clays as to former ice-movements agrees with that furnished by the striæ on the rocks. Over the whole of the districts lying to the south of the Silurian uplands the boulder-clays have been mainly derived from the southern hills, as is shown by the abundance in these clays of pieces of readily recognisable Lower Silurian rocks. The Spango granite, for instance, is found as far north as the Hagshaw Hills, on the left bank of the Douglas Water. Pieces of the Afton Water and Knipes granite likewise occur over the Carboniferous tracts to the north. Fragments of the Haggis Rock are among the most easily detected stones in the boulder-clays, alike on the Carboniferous and Old Red Sandstone areas. While the Spango granite is found to the north, it occurs likewise in considerable quantity in the boulder-clay which lies in the valleys to the south and south-east, being traceable up the Wanlock Glen for three miles. Pieces of Carboniferous sandstone are also found over the same district. Small fragments of gneiss and mica-schist are met with in the boulder clay of Glenmore and

Guelt Waters. We have here, therefore, a repetition of the proof formerly adduced, that in Ayrshire lay the meeting-place of the masses of ice which moved southward from the Highlands, and northward from the Silurian uplands of Galloway, Nithsdale, and Clydesdale.*

94. In some of the large valleys, as in those of the waters of Ayr, Glenmore, and Guelt, the boulder-clay contains interstratified beds of sand, clay, and gravel. These sometimes exceed forty feet in depth, as at Bullion Scars on Glenmore Water, where they are overlaid with boulder-clay, while their base is not seen. Such stratified intercalations are thickest along the centre of the valleys, on either side of which they die out, and disappear wholly over the hills.

95. **Old River Channels below the Boulder Clay.**—Indications of former river-courses are sometimes found under the drift in the course of mining operations. Thus, in the valley of the Nith, to the west of Kirkconnel, a series of borings showed the existence of a deep trench worn out of the Carboniferous rocks, and filled up with boulder-clay. This trench was probably at one time the water-course of the Nith, which has since then been forced to cut a gorge for itself out of the rocks, without regaining its old channel. In the coal workings between Old Kelloside and Drumbuie, the Splint coal was found to be cut out by boulder-clay, at a depth of ten fathoms. But mines were driven through the obstruction, and the coal was regained, on the other side of what seems to have been another portion of a river-channel. A little to the east of Sanquhar a similar buried water-course was encountered in working the Daugh coal, and in this instance sand was found to lie between the boulder-clay and the rocks below.

96. **Sands and Gravels.**—Several good examples of the Upper or Kame or Sandy Drift occur in the area represented upon this Map. Some conspicuous kames run in a north-westerly direction along the railway valley near New Cumnock towards the plains of Ayrshire, and south-eastward down the valley of the Nith to the beginning of the gorge below Sanquhar. A straggling line of kames may be traced over the moors between New Cumnock and Muirkirk. At the latter village they are seen in well-marked parallel ridges, chiefly on the south side of the valley of the Ayr; but they cross the Ayr valley and sweep by Glenbuck over into the Lesmahagow district. A strip of gravel, not distinctly ridged into kames, stretches over Burnfoot Moor across the Greenock Water, and expands on the water-shed (about 1000 feet above the sea) into a platform, which, though now much cut down by streams, seems to suggest that it once ran up the Ayr valley into that of the Douglas. Similar deposits are met with in the latter valley below Carmacoup.

97. Another much denuded platform of sand and gravel follows the 1000 foot contour line along the south side of Buckstane Hill and the hills south-westwards to Thirstane round to Wildshaw. This area is not connected with the Douglas Water area, but belongs to the Drift series of the Clyde valley. The peculiarity of this deposit is the number of striated stones found in it.

98. **Erratic Blocks.**—Boulders of the Spango granite are shown over the hills northwards as far as the Hagshaw range. In like manner, pieces of the Knipes granite are found over the New Cumnock area. Blocks of the Cairnsmore granite occur abundantly to the north of that hill, particularly up to and along a height of 1700 feet. The boulders seem to have streamed through cols lower than 1700 feet, and are found at that or a less height in the lower part of the valleys which have no col at their top, but end in a corrie. Further to the east, fragments of the

* See *Explanation to Sheet* 14 of the Geological Survey of Scotland, p. 24.

white Cairn Table sandstone are strewn abundantly over the hills to the north and north-east, ranging even as far as the southern end of the Pentland Hills.

99. **Moraines.**—The higher points of the Silurian uplands during the late stages of the Glacial Period nourished groups of glaciers, which have left traces of their existence in numerous rubbish heaps or *moraines*. The most marked moraines are those in the high grounds to the south-west of the Nith, the greater mass of elevated land in that district probably allowing of the greater development and continuance of the glaciers. Moraine stuff, either heaped into mounds or strewn over the valley bottoms, is found in most of the valleys diverging from the high grounds at the south-west corner of the Map.

100. The best marked series of moraines occurs in the valley of the Holm Burn, one of the tributaries of the water of Ken. From the point where the south edge of the Map crosses the burn to its source there is a regular series of moraine mounds on both sides of the valley, rising tier above tier for some distance up the hill-sides. Some of the mounds are of a conical shape, but most of them have the form of long winding ridges, with a marked bend towards the centre of the valley. They beautifully illustrate the common horse-shoe shape of moraines. About half-way up the valley the largest of the mounds occur on the left side, where the concentric arrangement is well seen; and along this same side, too, their upper limit is defined by a continuous line of small conical heaps. The mounds of the Holm Burn vary in size from five to twenty feet in height. Blocks of hard greywacke are seen perched on their tops, but none of these are of large dimensions. A few massive ones are to be seen on the right hill-slope near the col. Three of them were roughly estimated to contain 480, 420, and 135 cubic feet respectively. The hollows between the mounds are filled with peat and marshy vegetation. At the junction of the Allwhanie Cleuch with the main stream, a pretty large alluvial flat occurs, which probably marks the site of an old lochan, dammed back by the large heaps of moraine stuff which occur at this part of its course. Several excellent sections of the same detritus are seen where the burn has cut through the mounds. It consists of a loose gravelly and sandy earth, with well-rounded stones, varying in colour from light blue to yellow, and without any bedded arrangement. In one section the proportion of scratched stones was found to amount to one-fifth of the whole. In others, the finding of a striated stone was not so easy. On the left side the moraines rise to a height of 250 feet above the level of the stream. The upper limit is about 1600 feet, and the lower about 950 feet, above the level of the sea. Some isolated mounds occur, just beyond the edge of this sheet, on the right-hand side of the valley, which resemble true moraines. These, however, will be alluded to in connection with the sheet to the south.

101. Moraines, more or less perfectly defined, likewise occur in the valleys of the Polvaddoch Burn, Long Burn, and Spout Burn, flowing southwards from the chain of heights extending to the east of Cairnsmore of Carsphairn, in the valley of the Clennoch Burn running westward, and in those of the Montraw and Afton which trend to the north. Even in the less elevated ground lying to the east of the head-waters of the Ken, moraine mounds occur on the streamlet which joins the right bank of the Shinuel Water near Troston Hill. Northwards also some distinctly marked mounds of similar origin are scattered along the course of the Euchan Water from Euchan Head for a distance of about three miles down to Benzien Craig. In these and other examples the moraine stuff distinctly rests upon a flow of boulder-clay which covers the bottom of the valley.

102. The more limited area of high ground forming the group of the Lowther Hills appears also to have nourished a little independent group of glaciers, for mounds, probably of morainic origin, occur in the valley of the Shortcleuch Water near the foot of Glen Franka Burn, and in the Windgate Burn and Dun Grain, all flowing down the north-west side of the ridge. On the opposite or south-east side similar mounds are met with at the head of the Dalveen Pass, among some excellent examples of *roches moutonnées;* also in the course of the streamlets which descend from the Lowthers into the Potrenick Burn, and in the Glengeith Burn. About a mile below Nether Fingland a curious kame-shaped mound of angular and subangular detritus has been cut through by the stream. This may possibly mark the position of a moraine mound, once continuous as a barrier across the valley.

Alluvium, Peat.

103. It is only along the bottom of the valleys, and chiefly those traversed by the larger streams, that any noticeable quantity of alluvial deposits occur. Two terraces (on the Nith, three) of gravel and sand are frequently found bordering the streams, and in one place where the Crawick and Spango Waters unite, these stream-terraces are as many as six in number. Several examples of lacustrine deposits, marking the site of former lakes, occur upon the Map. One of these is found at New Cumnock, where the kames of sand and gravel have at one time ponded back the waters of the Nith. The deposits accumulated in this ancient lake are coarse and gravelly at the mouth of the Afton Valley, but further east they pass into finely-stratified loam. Another old lake is indicated by laminated brown brick-clays (sometimes yielding deer's horns) at Cronberry Tileworks, near the south end of Aird's Moss.

104. Many of the hills in the Silurian have their flat tops covered with a thin coating of hill-peat. This coating gets deeper in the cols, but it is on the lower ground that the deepest and largest expanses of peat occur. Thus Aird's Moss covers an area of about three square miles, and is in many places more than twenty feet thick. Another large peat-moss occurs at Burnfoot Moor, a little further to the north-east.

Economic Minerals.

105. **Building Materials.**—In the Silurian tracts the harder greywacke beds are used for cottages and for 'dry-stone dykes.' The felstone-dykes of these districts are sometimes more capable of being dressed into blocks, as is shown by the masonry of the Leadhills Inn, though even there the corner-stones and lintels are usually of freestone. The more flaggy and tough beds of the Lower Old Red Sandstone are likewise used for fences, though further to the north, in the Lesmahagow district, they are the common building material. The porphyrites and pink felstones of this formation are not adapted for building purposes, except for dry-stone dykes. The sandstones or freestones of the Carboniferous series furnish admirable building stones. In the Calciferous Sandstones an enormous quantity of admirable building stone exists, though, from its lying mostly in the moorland tracts, it has not yet been much worked. Sandstones belonging to the Carboniferous Limestone series are quarried at Muirkirk; but the stone most wrought in this region is the freestone at the base of the Coal-Measures in Nithsdale. The upper red sandstones are also used. Since the opening up of the country by railways, the red sandstones of Mauchline and Dumfries are superseding the local stones for at least the finer kinds of masonry .

106. **Limestones.**—These are practically confined wholly to the Carboniferous districts. The cornstones belonging to the Calciferous Sandstone series are extensively worked at Craigdullyeart, to the north-west of Corsoncone, being much in request for agricultural purposes. As will be seen from the Map, a continuation of this cornstone runs as an intermittent band at the base of the Calciferous Sandstones, where these repose upon the Old Red Sandstone. The most valuable limestones are those occurring in the lower group of the Carboniferous Limestone series. They are most exclusively worked in the Muirkirk and Lugar district, where they serve as a flux in the smelting of iron. They are also worked at Wildshaw and Whitecleugh, and have been quarried at Penbreck and Kennox. In the upper division of the Carboniferous Limestone series, at least three limestones have been used, the uppermost or Blue Tour limestone sometimes attaining a thickness of seventy feet. They were formerly quarried on a more extensive scale than at present.

107. **Road-Metal.**—In the Silurian area the harder greywackes are used for road-metal, but, as a rule, are not durable. The intrusive felstones also, in the Silurian and Old Red Sandstone areas, where they can be conveniently got at, are much in request for similar purposes. The most serviceable rocks for making into road-metal are the Miocene dolerite dykes, the line of which may be sometimes traced for miles by the number of quarries opened along their course. In some parts of the Silurian district the gravel of the streams is used for road-metal.

108. **Hone-stones.**—Some of the softer felspathic flags or shales in in the Lowther group of the Llandeilo series might be used as water hones. Hones might also be formed out of the Old Red Sandstone shales of the Dippool.

109. **Pottery-Clays.**—The decomposing and least ferruginous varieties of the pink felstones of Muirkirk might be used as pottery-clays. Possibly, also, portions of the decomposing Spango granite might be available for the same purpose.

110. **Brick-Clays.**—The blue tills or fireclays of the Cement-stone group might be used for making bricks and tiles, as is now the case with the fireclays and shales associated with the M'Douald limestone, which are employed to furnish the bricks required in the Muirkirk Ironworks. At Sanquhar, the red marls and clays lying in the upper part of the Coal-Measures are available for making the coarser kinds of pottery and terra-cotta. Bricks and tiles are made from the alluvial clays already mentioned as occurring at Cronberry. Similar clays occur in the valley of the Ayr, and in other parts of the Map.

111. **Ores.**—The present Map includes one of the best known mineral fields in Scotland—that of the Leadhills.

Lead.—Galena has long been worked extensively in the Silurian rocks of Leadhills and Wanlockhead. The direction of the veins is indicated on the Map, and their general character may be gathered from the following description of a part of the New Glencrieff vein, laid open in December 1868. The vein here hades to the east at 70°–75°. Beginning at the east or 'hanger' side, the order of metals is as under:—

a. Greywacke; part of the general Silurian rock or 'country.'
b. 'Black Jack' (Zinc blende), decomposing into clay. ½ inch.
c. 'Vein stuff;' Greywacke ground up, and mixed with quartz. 1½ inch.
d. Calc-spar. ½ inch to 1 inch.
e. Galena. ½ inch.
f. Vein stuff, similar to *c.* Quartzose, and graduating into pure Quartz near the floor of the level. 2 to 3 inches.
g. Blue greywacke; joints veined with calcareous matter. 3½ feet.
h. Hard, fine, compact Quartz, with iron pyrites in 'flowers;' *i.e.* the crystals are scattered through the mass, and are not connected. 7 inches.

k. Alternating irregular layers of Barytes and Galena. 8 inches.
l. Vein stuff, similar to *c*. 4 inches.
m. Greywacke (the 'ledger side' of the vein), marked with vertical slickensides.

The section is about six feet high. A 'string' of Black Jack commences at the roof of the level in *g*, and cuts through all the layers on to *m*, which it enters near the floor. *a*, *g*, and *m* are 'country.' The other layers and the string are properly the vein. The veins vary at every step, and are sometimes remarkably rich in lead ores; while, on the other hand, the levels are sometimes driven for many fathoms without meeting with any.

Further westwards, a true vein of galena was tried at in the Silurian rocks to the south of New Cumnock, but was abandoned.

Iron.—Hæmatite, but not in workable quantity, has been found on the Ponnel Burn at the north-west corner of the Map, also on the northern slope of Tewsgill to the east of Abington. It occurs also among other ores in the veins of the Leadhills and Wanlockhead tract. The most valuable ores of iron are the black-band ironstone of Lugar, Muirkirk, and Glespin, and the ordinary clay-band ironstones of Muirkirk. The position of these beds is shown in the section already given (par. 63), and also on the Map.

Antimony.—A rich vein of antimonite, or sulphuret of antimony, was formerly worked on part of the Knipes granite at a place called Hare Hill, to the south-east of New Cumnock. Owing to the death of the proprietor, the workings have been discontinued, but many tons of the ore are still to be found near the mouth of the old mine. Small quantities of antimony are also met with in the mineral veins of the Leadhills tract.

Manganese.—On the old Sanquhar road, about a mile north-east from Wardlaw Hill, a vein of barytes occurs, containing small quantities of finely mammillated pyrolusite. The same ore is met with also in the veins of Leadhills and Wanlockhead.

Zinc.—'Black Jack,' or sulphuret of zinc, is a common constituent of the galena veins, and occurs there sometimes in considerable quantity.

Copper.—Copper-pyrites is likewise an occasional constituent of the Leadhills and Wanlockhead mineral veins.

Silver.—The galena of Wanlockhead is sufficiently argentiferous to allow of the extraction of the silver with profit.

Gold.—For more than three centuries gold has been collected in small quantities from the alluvia of the streams in the Leadhills and Wanlockhead district.

Barytes.—In this place may be mentioned the existence of a barytes vein, which is in many places fifteen feet thick, and may be traced from near the head of Gass Water for two miles in a north-westerly direction as far as Knockbreck. Another barytes vein, about three feet thick, sometimes containing hæmatite, occurs on the flank of Auchensaugh Hill, lying to the east of the Douglas coal-field.

112. **Fuel.**—Except peat, no fuel exists in the Silurian or Old Red Sandstone districts. The carboniferous tracts, however, furnish the coals of the Muirkirk, Cumnock, Glespin, and Sanquhar coal-fields, which have been already referred to. In some of these fields the shales are sufficiently bituminous to be capable of being used for the manufacture of paraffin oil.

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